Appendix A – Analysis Parameters and Evaluation Framework

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MEMORANDUM

TO: C/CAG Technical Advisory Committee

FROM: Terry Klim

DATE: March 12, 2003

SUBJECT: Technical Memorandum #1 - Analysis Parameters and Evaluation Framework P/A No. 03018-000x002

Introduction

The purpose of the Peninsula Corridor Ramp Metering Study is to examine the potential impacts of ramp metering along U.S. 101, I-380, and the northern portion of I-280 in San Mateo County. This memorandum summarizes the steps in the analysis process, describes the proposed evaluation framework that will be used, and highlights the key outputs or performance measures that will be reported at each step of the analysis process.

Analysis Process

The analysis process consists of four primary elements that correspond to specific tasks in the study scope of work. The four analysis elements are:

- **Ramp Geometric Assessment (Task 3)** – This element involves an assessment of each on-ramp with respect to characteristics such as potential meter location, queue storage, and potential for modification to increase storage, meter capacity or accommodate an HOV-priority lane.
- **Freeway Operational Analysis (Task 7)** – This element focuses on the analysis of the freeway system to determine whether ramp metering would indeed improve operations on the freeway.
- **Diversion Assessment (Task 8)** – This element includes examination of diversion of traffic from the freeways to the arterials and impacts on the arterial roadway system. As part of this step, the potential diversion from single occupant vehicles (SOVs) to high-occupancy vehicles (HOVs) or carpools will also be examined.
- **Local Street Analysis (Task 9)** – In this element, the relative change in operations at selected intersections will be examined.

The analysis conducted for this study will examine two horizon years: 2010 and 2020. For both years, analysis will be conducted for both the AM and the PM peak time periods.

A more detailed discussion of the methodology to be used for the individual analysis elements is presented in the study scope of work.

Evaluation Framework Overview

One of the first tasks in this study is to define the framework to be used to evaluate the projected impacts of ramp metering in the study area. This framework is intended to identify the specific performance measures and outputs that will be used in and reported as part of the analysis process for this study.

An extensive set of performance measures and outputs may be generated from the four analysis elements listed above. However, it was recognized that using all of potential information would likely overwhelm analysts and decision-makers. Thus, a critical task was to identify a subset of performance measures that would provide for a comprehensive, but also understandable and meaningful, presentation of results. In this effort, the candidate measures were evaluated against the following criteria:

- Ability to address the concerns and questions of stakeholders;
- Easy to understand and familiar to evaluators;
- Obtainable from the analysis tools and methodologies used in this study;
- Sensitive to changes/impacts caused by ramp metering; and
- Sensitive to perceptions of "users" (motorists).

Also taken into consideration were factors such as the different types of network components (freeways, ramps, adjacent intersections, and arterials) to be analyzed; the need to look at different levels of details, ranging from system wide measures to facility- and trip-specific measures; the number of issues or questions to be addressed; and the extended and multiple time periods being analyzed.

The evaluation framework for the Peninsula Corridor Ramp Metering Study is presented in Table 1. This evaluation framework is structured around a base set of questions or issues expected to be of primary concern or interest to those that would be responsible for and affected by ramp metering. The questions presented in Table 1 were derived from the information presented in the Request for Proposals, an understanding of ramp metering, and past experience with similar projects. For each question, a number of performance measures or analysis outputs have been identified that could be used in describing the results and in developing conclusions.

Table 1 – Evaluation Framework

Performance Measure/Output	Application		Analysis Element
	Geographic[1]	Time Period	
What are the opportunities for providing preferential access to the freeways for HOVs?			
Candidates for HOV Priority Lanes	All on-ramps	N/A	Ramp Geometric Assessment
What impact will ramp metering have on freeway operations?			
Average Mainline Speed	Selected freeway sections	By hour	Freeway Operational Analysis
Mainline Queue/Congestion Characteristics	Systemwide	By time slice for entire period	Freeway Operational Analysis
Freeway VHT,VHD	Systemwide	Total for period	Freeway Operational Analysis
Point-to-Point Travel Time	Selected O/D pairs	Selected time slices	Freeway Operational Analysis
Fuel Consumption	Systemwide	Total for period	Freeway Operational Analysis
Is ramp metering complementary to the Route 101 Auxiliary Lane Program?			
Auxiliary Lane Assessment	Systemwide	N/A	Freeway Operational Analysis
How will metering impact ramp operations?			
Average Ramp Delay	All on-ramps	Entire period Selected time slices	Freeway Operational Analysis
Ramp Queue Length	All on-ramps	Selected time slices	Freeway Operational Analysis
What are recommended meter operating parameters?			
Listing of Ramps with Active Metering	Systemwide	Entire period	Freeway Operational Analysis
Hours of Meter Operation	Systemwide	Entire period	Freeway Operational Analysis
Optimal Metering Ranges	All on-ramps	Entire period	Freeway Operational Analysis
Will the distribution of ramp metering benefits and costs be shared equitably throughout the study area?			
Point-to-Point Travel Time	Selected O/D pairs	Selected time slices	Freeway Operational Analysis
Average Ramp Delay	All ramps	Entire period Selected time slices	Freeway Operational Analysis

Table 1 – Evaluation Framework (continued)			
Performance Measure/Output	**Application**		**Analysis Element**
	Geographic[1]	**Time Period**	
Will ramp metering, if it includes HOV ramp by-passes, be likely to impact mode choice?			
Point-to-point travel times (mixed vs. HOV)	Selected O/D pairs	Selected time slices	Freeway Operational Analysis
Will ramp metering lead to the diversion or re-distribution of traffic between the freeway and arterial streets?			
VHT (freeway vs. arterial)	Systemwide	Total for 3-hour peak period	Diversion Assessment
"Diverted Traffic" Volumes	Selected segments – freeway, arterials, on-ramps	Total for 3-hour peak period	Diversion Assessment
As the result of possible diversion, how will arterial operations be affected?			
"Diverted Traffic" Volumes	Selected segments – arterials, intersections	Total for 3-hour peak period	Diversion Assessment
Link LOS (V/C ratio)	Selected segments	Total for 3-hour peak period	Local Street Analysis
Intersection LOS Grade/Average Vehicle Delay	Selected intersections	Peak hour	Local Street Analysis
Ramp Queue Length	All on-ramps	Entire period	Freeway Operational Analysis
What improvements are needed at the ramps and on local streets to mitigate the impacts of ramp metering and maximize its' potential effectiveness?			
Candidate for Widening (Improvement Feasibility)	All on-ramps	N/A	Ramp Assessment
Ramp Queue Length	All on-ramps	Entire period	Freeway Operational Analysis
Mainline Queue/Congestion Characteristics	Freeway systemwide	Entire period	Freeway Operational Analysis
Intersection LOS	Selected intersections	Peak hour	Local Street Analysis

Note:
1. A segment is defined as a portion of roadway between adjacent interchanges or intersections. A section refers to a longer portion of roadway that may include multiple segments.

Source: DKS Associates

It should be noted that the performance measures cover a variety of time periods. This is often necessitated by the specific tool being used to generate the results. For the freeway analysis, a four-hour peak period model will be developed that will provide outputs in 15-minute timeslices. However, for the diversion assessment, the existing 3-hour peak period travel forecasting model will be used. For the intersections, the peak hour will be analyzed consistent with current practices and the analysis tool being used.

The following sections describe the specific performance measures and outputs that will be used to describe the results and develop conclusions as part of each analysis element. It should be noted that in some cases measures or outputs beyond those identified in the evaluation framework will be developed as part of the individual analysis elements. These additional measures or outputs may provide valuable background information and may be inputs to the analysis models or subsequent recommendations.

Element 1- Ramp Geometric Assessment

In this element, an inventory of all on-ramps will be conducted. This inventory will provide data regarding existing design characteristics (e.g. type of ramp, storage length) and an assessment of the potential feasibility for improvements (e.g. widening for increased throughput or storage, or addition of an HOV priority lane). This information will be used to identify ramp improvements that may be assumed in the future year analysis. Table 2 summarizes the key performance measures or outputs that will be reported as part of this analysis element.

Table 2
Ramp Geometric Assessment Performance Measures/Outputs

Performance Measure/Output	Description	How Reported
Queue storage length	Estimated distance between existing or proposed ramp meter stop bar and end of ramp. Input to freeway analysis model.	Tabular – for all on-ramps
Throughput capacity	Number of vehicles that can be served under meter conditions. Based on number of lanes at meter and maximum metering rate. Input to freeway analysis model.	Tabular – for all on-ramps
Improvement feasibility	An conceptual assessment of potential feasibility for improvements (e.g. widening for increased throughput or storage, or addition of an HOV priority lane) based on available ROW, grades, adjacent obstructions, etc. To be reviewed with TAC before coding into freeway analysis model.	Tabular – for all on-ramps
Candidates for HOV Priority Lanes	Derived from above assessment. To be reviewed with TAC before coding into freeway analysis model.	Tabular

Source: DKS Associates

Element 2- Freeway Operational Analysis

The objective of this element is to determine if ramp metering can provide any significant operational benefits to the freeway in the study area. The main tool to be used in the freeway operational analysis is a simulation program called FREQ (pronounced free-q). FREQ is designed for evaluating traffic management and traffic control alternatives, and is particularly well-suited for analyzing how well ramp metering might improve freeway operations, and estimating the lengths of resulting ramp queues. Separate FREQ models will be developed for each horizon year (2010 and 2020) and for each peak period. Specifically, the models will cover both 4-hour AM (6 to 10) and PM (3 to 7) peak periods.

Outputs from FREQ include traffic performance tables, contour diagrams of traffic performance, and freeway summary tables. FREQ provides a wide variety of performance data as output, and generally in great detail. While these data are needed for assessing traffic performance on a technical level, they are not always appropriate for reports or presentation. Table 3 identifies the key performance measures that will be reported as part of this element.

Table 3
Freeway Operational Analysis MOEs

Performance Measure/Output	Description	How Reported
Queuing/Congestion Characteristics	This measure examines the location and length of queues. Queuing diagrams are generated by FREQ for each 15-minute timeslice modeled. Comparison of these diagrams by timleslice provides an indication of the duration of congestion/queuing. May be used to identify potential improvements to address bottlenecks.	Map of peak hour queues Figures for selected queues showing length at multiple times throughout peak period
Average Mainline Speed	FREQ reports average speed for each freeway segment for each timeslice.	Tables and bar charts showing average speed at various times for selected locations
Vehicle Hours of Travel (VHT)	The product of the volume on a segment or ramp multiplied by the time to traverse that link (time = length/speed). Computed directly by FREQ.	Tables showing mainline, ramp and combined VHT for entire period
Vehicle Hours of Delay (VHD)	The difference between the actual recorded VHT and the VHT expected with free flow speeds.	Tables showing mainline, ramp and combined VHD for entire period

Table 3
Freeway Operational Analysis MOEs

Performance Measure/Output	Description	How Reported
Point-to-Point Travel Time	Forecasted travel times for a set of selected on-ramp to off-ramp pairs. The selected O/D pairs will represent a mix of trip lengths and locations. Determined using outputs from FREQ for individual ramps and freeway segments. To assess the varying impacts of through the analysis period, travel times will be calculated for both the peak hour and a shoulder hour. Provides indicator of overall operational impact of ramp metering, and the distribution of these impacts for various trips.	Tabular – peak hour comparison and shoulder hour
Point-to-Point Travel Time (mixed flow vs. HOV)	For selected O/D pairs, comparison of SOV versus HOV travel times. Reflects potential travel time advantages from HOV priority lanes at meters and on freeway mainline.	Tabular – peak hour comparison and shoulder hour
Ramp meter operating characteristics	Includes hours of operation, which meters are operating for each period, and metering rates. These are largely inputs to FREQ model determined from operational policy, on-ramp volumes versus maximum metered flow rate, etc. For a specific operational objective, FREQ can optimize individual metering rates.	Tabular – maximum queue Figure highlighting ramps where queue extends beyond ramp
Ramp Queue Length	Maximum number of vehicles in queue at ramp meter for each timeslice. Direct output from FREQ.	Tabular – maximum queue Figure highlighting ramps where queue extends beyond ramp
Average Ramp Delay	Delay at on-ramp due to meter and/or mainline congestion. Direct output from FREQ. Used as input for diversion assessment procedures.	Tabular – average peak delay by ramp; comparison between without and with metering
Fuel Consumption	Estimated consumption based on travel distance, speeds, and assumed vehicle mix. Computed directly by FREQ.	Tabular comparison of total fuel consumption for entire period
Auxiliary Lane Assessment	Qualitative assessment as to whether ramp metering is complementary to the Route 101 Auxiliary Lane Program.	Text
Source: DKS Associates		

Element 3 – Diversion Assessment

The basic objective of the diversion analysis was to translate changes in freeway and ramp travel times to changes in trip routing or assignment. Ramp metering impacts travel times through added delays at ramps and reduced travel times on the freeway. These changes may affect decisions made by travelers regarding the route traveled and potentially mode of travel. In general, shorter trips (those for which ramp delays may represent a significant portion of the total travel time) may divert from the freeway to parallel arterials. For longer trips, time savings on the freeway may result in diversion from arterials to the freeway. Another aspect of diversion that must be addressed is that of shifting from one ramp to another. These localized shifts will impact ramp operations, as well as the operation of nearby intersections. A third aspect is the potential for mode shift from SOV to HOV travel if HOV-priority lanes are provided on metered ramps.

This assessment will be conducted using the FREQ models to provide ramp meter delays and SOV-versus-HOV travel times for the freeway, and the countywide travel demand model to predict changes in route assignment. To simulate the impacts of ramp metering using the countywide travel demand model, a fixed additional delay will be added to each metered on-ramp based on the additional number of minutes of delay due to the ramp meter as derived from the FREQ analysis results.

Table 4 identifies the key performance measures that will be reported as part of the Diversion Assessment. It should be noted that because the countywide travel demand model covers a 3-hour AM peak period and a 3-hour PM peak period, results derived from this model will necessarily only cover these same time periods and not the full 4-hour periods being modeled with FREQ.

Table 4
Diversion Assessment MOEs

Performance Measure/Output	Description	How Reported
"Diverted Traffic" Volumes	The forecasted 3-hour peak period volumes with and without metering for selected segments. Segments to include selected freeway and arterial links, plus all on-ramps. This is a principal measure of diversion. Because the focus of the analysis is on identifying the changes resulting from the introduction of metering, not on determining specific future year volumes, this comparison will based on forecasts direct from the travel forecasting model.	Tabular – change in ramp forecasts without and with metering Figure – map showing change in forecasted volume for selected segments
Vehicle Hours of Travel (freeway versus arterial)	VHT derived from travel forecasting model. Compare VHT on freeway versus arterial links for both without and with metering.	Tabular
Point-to-Point Travel Time (mixed flow vs. HOV)	For selected O/D pairs, comparison of SOV versus HOV travel times. Reflects potential travel time advantages from HOV priority lanes at meters and on freeway mainline. The relative difference between the SOV and HOV travel times under the No Meter and With Metering scenarios were used to judge whether the implementation of ramp metering with HOV bypasses may result in a shift between these two modes of travel.	Tabular – peak hour comparison and shoulder hour
Source: DKS Associates		

Element 4 – Local Street Analysis

This element will examine the potential impacts to local streets and intersections, with a focus on intersections adjacent to the on-ramps. Ramp meter queue length information from FREQ will be used to identify where queues may be expected to impact these intersections. For intersections identified in the diversion analysis as expected to experience significant changes in forecasted demands, LOS analysis will be conducted using TRAFFIX. For arterial segments further from the interchanges, an assessment of the segment capacity and ability to accommodate the increased demand will be conducted using link LOS (V/C ratio) criteria. For each intersection or arterial segment, peak hour LOS analysis will be conducted for both baseline (no metering) and with metering conditions only for the future year(s) where significant diversion is expected. The results of the queue assessment and LOS analysis will be used to identify potential improvements (e.g. queue spillback detectors, lane modifications, etc.) that will minimize impacts and maximize the effectiveness of ramp metering.

Table 5 identifies the key performance measures and outputs that will be reported as part of this analysis element. It is important to note that the intersection LOS/delay measures will be reported for only the peak hour in both the AM and PM periods. It must be stressed that as with other elements of the study analysis, the focus for the intersection analysis will be on identifying changes in predicted operations when ramp metering was introduced.

Table 5
Local Street Analysis MOEs

Performance Measure/Output	Description	How Reported
Forecasted Turn Movement Volumes	Future year intersection volumes based on existing counts and adjusted for forecasted growth from travel forecasting model for selected locations. Determined for both without and with metering conditions. Input to LOS analysis.	Tabular
Intersection LOS/Delay	Peak hour LOS analysis for selected intersections.	Tabular – comparison of LOS without and with metering
Ramp Queue Length	Maximum number of vehicles in queue at ramp meter for each timeslice. Direct output from FREQ.	Tabular – maximum queue Figure - highlight ramps where queue extends beyond ramp
Link LOS (V/C ratio)	Indicator of arterial segment LOS based on volumes forecasts directly from travel forecasting model.	Tabular – comparison of LOS without and with metering
Source: DKS Associates		

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Appendix B – On-Ramp Geometric Assessment

San Mateo Ramp Metering- On-Ramp Geometric Assessment (Revised)

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DATE: July 14, 2003

Introduction

This technical memorandum is the deliverable for Task 3 ("Conduct On-Ramp Geometric Assessment") for the Peninsula Corridor Ramp Metering Study. The objective of the Peninsula Corridor Ramp Metering Study is to assess the role of ramp metering for helping manage traffic within the Peninsula Corridor. The study area includes US Highway 101 (US 101) within San Mateo County, and the northern section of and Interstate 280 (I-280), from I-380 to the San Francisco County line.

The first part of the project focuses on the freeway operational impacts of ramp metering. The goal of this series of steps is to determine if ramp metering can provide any significant operational benefits to the freeways in the study area. This is being accomplished by developing traffic simulation models of the freeway systems for two horizon years (2010 and 2020), adding ramp metering to the systems, and comparing the predicted performance with and without ramp metering. If it is determined that ramp metering may benefit some or all freeways, the second part of the project will focus on the potential impacts to the arterial street system throughout the study network.

This memorandum describes the approach for conducting and presents the results of the on-ramp geometric assessment along US 101 and I-280. To effectively evaluate ramp metering, it is important to understand the potential for modifying and improving ramps to accommodate ramp metering. An inventory of all on-ramps was conducted to provide information on the existing design characteristics. This information will be used to identify ramp improvements that may be assumed in the future year analysis.

Methodology

There are two elements to conducting the on-ramp geometric assessment: documenting the existing on-ramp configuration, and identifying the potential feasibility for improvements. The assessment for both items is summarized on the attached spreadsheet, which also includes basic information on each interchange, as well as traffic volume data.

Existing Configuration

The type of information collected in determining the existing ramp configuration includes the location of any existing metering equipment, the number of lanes (at the meter point and upstream), and the estimated storage capacity (number of cars).

The number of lanes and availability of metering equipment was determined through field investigations conducted on March 4, 2003 and May 16, 2003. Caltrans also was consulted to obtain information on any metering equipment. Aerial photos obtained from the San Mateo County Transportation Authority (TA) were used to determine the storage length available on each on-ramp. The storage length currently available on the on-ramps was determined by using the recommended minimum vehicle spacing of 9 meters in the Caltrans Ramp Meter Design Guidelines. For ramps that do not currently have metering equipment installed, the location of the stop bar was assumed, based on design criteria from the Caltrans guidelines.

Feasibility for Improvements

The type of information collected to assess the potential feasibility for improvements is more qualitative than that of the existing configurations. The first step in assessing feasibility was to identify planned and/or programmed improvements to interchanges. This information was obtained through the TA, Caltrans, and local jurisdictions. Beyond planned projects, the potential for widening either for increased throughput or storage, which includes the addition of an HOV lane, was assessed through field investigations. The Caltrans Ramp Meter Design Guidelines states that an HOV preferential lane shall be provided at all ramp meter locations.

Ramp throughput refers to the number of lanes at the stop bar of the ramp, and it determines the metering rate. For example, a one-lane ramp has a maximum metering rate of 900 vehicles per hour (vph), but if its demand exceeds 900 vph, it is difficult to meter effectively. Therefore, it may be beneficial to increase the throughput of some ramps.

Ramp storage refers to the number of vehicles who can be in a queue without affecting arterial traffic. With more storage, ramp metering may be more effective in improving mainline traffic performance, so another option is to increase the storage for some ramps.

A field assessment of each ramp was undertaken, and the potential for expansion was assessed using a three-point scale. The assessment was based on a technical, but qualitative, observation of the right-of-way, grading, and structural characteristics of the existing ramps. Ramps that could be expanded at a moderate cost were graded as high ("H"), those ramps that might present some problems for expansion or might be relatively expensive were graded as medium ("M"), and those ramps that would be prohibitively expensive to expand were graded as low ("L"). Factors that results in some "M" and "L" ranking included the presence of a soundwall, retaining wall, creek, or marsh; right-of-way issues, and ramps that are located on structures.

Results

The results of the on-ramp geometric assessment are summarized in Table 1 and presented graphically in Figure 1. Appendix A provides detail on the assessment of each individual ramp.

The "Existing Configuration" column identifies the current configuration of the on-ramps. Note that about 40 percent of the ramps have metering equipment already installed; with a higher concentration on I-280 and the south end of US 101.

The next set of columns lists the planned and programmed improvements, in terms of where ramps may be realigned, widened, and/or metering equipment will be installed. The interchanges where improvements are planned include Oyster Point, Broadway, Ralston/Harbor, Holly, Marsh, Willow, and University. Based on these improvements, geometric configuration, and ramp volumes, a preliminary assessment of the potential metering locations is also provided. Most (about 80%) ramps were assigned a "yes". The ramps that did not are expected to have volumes that are too high or low for effective metering, or have geometric characteristics (e.g., system interchange ramps) that would make ramp metering ineffective or a potential safety issue.

The next set of columns, labeled "Assessment for Widening" summarizes the potential for widening, based on current and future geometry. Overall, just over half (55%) of the ramps were graded as "L" for ramp throughput (widening at the stop bar), while 29% and 17% were graded "M" and "H" respectively. About two-thirds (70%) of the ramps were graded as "L" for ramp storage, with the rest about equally split between "M"s and "H"s. Note, however, that many of the ramps are already configured for ramp metering, so many of the ramps will not require widening.

TABLE 1
Summary of On-Ramp Geometry Assessment (Number of Ramps)

	Widen for Throughput			Widen for Length/Storage		
Category	**US 101**	**I-280**	**Total**	**US 101**	**I-280**	**Total**
High ("H")	11	1	**12**	7	4	**11**
Medium ("M")	16	4	**20**	10	1	**11**
Low ("L")	33	6	**39**	43	6	**49**
Total	**60**	**11**	**71**	**60**	**11**	**71**

All of these data were used to develop a recommendation for future ramp metering and improvements, under two scenarios. The "Recommendations for Ramp Metering Improvements" columns outline the specific suggestions for ramp improvements, using two scenarios:

- Scenario 1: A "conservative" scenario, minimizing capital improvements except where critical and relatively easy.
- Scenario 2: An "aggressive" scenario, considering more ramp improvements where feasible ("H" and "M" ratings) and appropriate.

The table indicates the specific recommendations for widening for the addition of an HOV priority lane, an additional mixed flow metered lane, and/or additional ramp storage. Any one, two, or three might be recommended at each on-ramp.

The specifics of the recommendation depend on the ramp, but some general guidelines were followed. Scenario 1 improvements were generally limited to "H" locations. Where widening for throughput was considered, the volume at the ramp was used to determine if an HOV priority lane would be added or a second metered lane would be added. For higher volume ramps, where the second metered lane would likely be needed, the latter was selected. Note that improvements were not recommended in some locations with "H" rating, because they would not be expected to be beneficial for ramp metering.

Of the 68 ramps identified for metering, the following improvements are recommended:

Scenario 1: 6 HOV, 4 throughput, and 6 storage

Scenario 2: 16 HOV, 12 throughput, and 16 storage

Improvements are identified in approximately 18% of the ramps (12 of 68) in Scenario 1 and 38% (26 of 68) in Scenario 2. Note that some ramps have more than one improvement.

Next Steps

The assessment described here will be used to identify the determine the ramp metering parameters in the freeway analysis models that have been developed for the future year analysis in Task 6. These will be applied to determine to the potential benefits of ramp metering.

Appendix A

Detail Summary of Ramp Geometric Assessment

Table 4-1 On-Ramp Geometric Assessment Summary

		Existing Configuration			Planned/Programmed Improvements					Scenario 1								Scenario 2							
				Dedicated			Dedicated	Assessment for Widening		Modification				Queue Storage				Modification				Queue Storage			
Interchange Name	**Interchange Type/On-ramp**	**Metered?**	**Lanes***	**Access**	**Metered?**	**Lanes***	**Access**	**Thru**	**Length**	**HOV**	**Thru**	**Storage**	**Lanes***	**Ramp**	**Access**	**Spillover**	**Total**	**HOV**	**Thru**	**Storage**	**Lanes***	**Ramp**	**Access**	**Spillover**	**Total**
ORTHBOUND US 101																									
University Avenue	Full Cloverleaf/CD Road																								
	Loop On-ramp	Yes	1					L	L				1	56			56				1	56		**100**	156
	Diagonal On-ramp	Yes	1					L	L				1	4			4				1	4		**100**	104
Willow Road	Full Cloverleaf																								
	Loop On-ramp	No	1		Yes	1+HOV		L	L				1+HOV	19			19				1+HOV	19		**50**	69
	Diagonal On-ramp	No	1	Yes	Yes	1+HOV		L	L				1+HOV	23			23				1+HOV	23		**50**	73
Marsh Road	Partial Cloverleaf																								
	Loop On-ramp	Yes	1					L	L				1	15			15				1	15		**50**	65
	Diagonal On-ramp	Yes	2+HOV+Pullout	Yes				L	L				2+HOV	36	7		43				2+HOV	43		**50**	93
Woodside Road / Seaport Boulevard	Partial Cloverleaf																								
	Loop On-ramp	No	1		Yes	1+HOV		M	L				1+HOV	21			21		yes	yes	2+HOV	**42**		**50**	92
	Diagonal On-ramp	No	1		Yes	1+HOV		M	L				1+HOV	20			20				1+HOV	20		**50**	70
Whipple Avenue	Partial Cloverleaf																								
	Loop On-ramp	No	1		Yes	2	Yes	M	L				2	32	20		52			yes	2	**104**		**50**	154
	Diagonal On-ramp	No	1		Yes	1		L	L				1	14			14				1	14		**50**	64
Holly Street	Full Cloverleaf/CD Road																								
	Loop On-ramp	No	1		Yes	1+HOV		M	M				1+HOV	40			40				1+HOV	40		**50**	90
	Diagonal On-ramp	No	1		Yes	1+HOV		M	M				1+HOV	25			25				1+HOV	25		**50**	75
Ralston Avenue	Full Cloverleaf/CD Road																								
	Loop On-ramp	Yes (on CD)	1+HOV		Yes	1+HOV	Yes	L	L				1+HOV	27			27				1+HOV	27		**50**	77
	Diagonal On-ramp	Yes	1+HOV		Yes	2+HOV	Yes	L	L				2+HOV	64	31		95				2+HOV	95		**50**	145
E. Hillsdale Boulevard	Partial Cloverleaf/CD Road																								
	Loop On-ramp	Yes	1	Yes				H	H		yes	yes	2	**56**	19		75	yes	yes	yes	2+HOV	**150**		**50**	200
	Diagonal On-ramp	Yes	1					L	L				1	32			32				1	32		**50**	82
Junction Route 92	Multi-Level System Interchange																								
	Loop On-ramp	No	1					L	L				1	**35**			35				1	35			35
	Diagonal On-ramp	No	2										3	136							3	136			136
Kehoe Avenue	Buttonhook																								
	Hook On-ramp	No	1					H	L	yes			1+HOV	6			6	yes			1+HOV	6		0	6
3rd Avenue	Full Cloverleaf/CD Road																								
	Loop On-ramp	No	1		Yes	1		L	L				1	28			28				1	28		0	28
	Diagonal On-ramp	No	1		Yes	1		L	L				1	12			12				1	12		0	12
Dore Avenue	Isolated Off-ramp																								
Peninsula Avenue	Buttonhook																								
	Hook On-ramp	No	1		Yes	2	Yes	L	L				2	70	4		74				2	74		0	74
Anza Boulevard	Buttonhook																								
	Hook On-ramp	No	1		Yes	1		H	M	yes			1+HOV	26	25		51	yes		yes	1+HOV	26		25	51
Broadway	Modified Trumpet																								
	Hook On-ramp	No	1		Yes	2	Yes	L	L				2	30			30				2	30		0	30
Millbrae Avenue/SFO	Braided/CD road																								
	Millbrae/frontage road entrance	No	2					L	L				2	133			133				2	133		0	133
	SFO On-ramp	No	1					L	L				1	65			65				1	55		0	55
San Bruno Avenue	Isolated Off-ramp																								
Junction Route 380	Multi-Level System Interchange																								
	San Bruno CD road entrance	Yes - U/G	2					L	L				2	138			138				2	138		0	138
	I-380/N. Access On-ramp	No	2					L	L				2	55											
Produce/Airport Boulevards	Buttonhook																								
	On-ramp	No	1	Yes				L	L				1	10	6		16				1	16		0	16
Grand Avenue	Buttonhook																								
	On-ramp	No	1					L	L				1	42			42				1	42		0	42
Oyster Point Boulevard	Modified Diamond																								
	On-ramp	No	1		Yes	2	Yes	H	H				2	36	9		45	yes			2+HOV	45		0	45
Bayshore Boulevard/Sierra Point	Flyover																								
	On-ramp	No	1	Yes				L	M				1	33	2		35	yes			1+HOV	35		0	35
Harney Way	Buttonhook																								

Table 4-1 On-Ramp Geometric Assessment Summary

		Existing Configuration			Planned/Programmed Improvements			Assessment for Widening		Scenario 1								Scenario 2							
				Dedicated			Dedicated			Modification				Queue Storage				Modification				Queue Storage			
Interchange Name	**Interchange Type/On-ramp**	**Metered?**	**Lanes***	**Access**	**Metered?**	**Lanes***	**Access**	**Thru**	**Length**	**HOV**	**Thru**	**Storage**	**Lanes***	**Ramp**	**Access**	**Spillover**	**Total**	**HOV**	**Thru**	**Storage**	**Lanes***	**Ramp**	**Access**	**Spillover**	**Total**
OUTHBOUND US 101																									
Harney Way	Buttonhook																								
	Diagonal On-ramp	Yes	1		Yes	2	Yes	H	H				2	34			34	yes		yes	2+HOV	**68**		0	68
Bayshore Boulevard/Sierra Point	Buttonhook																								
	Sierra Point On-ramp	Yes	1		Yes	1	Yes	H	H				2	28			28			yes	2	**56**		0	56
	Bayshore On-Ramp				Yes	1+HOV	Yes						1+HOV	37			37				1+HOV	37		**50**	87
Oyster Point Boulevard	Split																								
	On-ramp	No	1		Yes	2	Yes	M	L				2+HOV	66	8		74				2	84		**50**	134
Grand Avenue	Isolated Off-ramp																								
Produce/Airport Boulevards	Split Buttonhook																								
	On-ramp	No	2	Yes				H	H	yes			2	11			11	yes		yes	2+HOV	**22**		0	22
I-380/San Bruno	Multi-Level System Interchange																								
	WB I-380/North Access Rd On-ram	No	1					L	L				1	75			75								0
	EB I-380 On-ramp	No	2										2	260											
	San Bruno On-ramp	No	1					L	L				1	26			26				1	26		**50**	76
San Francisco Airport	Multi-Level																								
	International Terminal On-ramp	Partial	1					M	L				1	86			86	yes			1	86		0	86
	Domestic Terminal On-ramp	Partial	2					M	L				2	180			180	yes			2	180		0	180
Millbrae Avenue	Partial Cloverleaf																								
	Loop On-ramp	No	1					M	L				1	24			24	yes			1	24		**50**	74
	Diagonal On-ramp	Yes	2+HOV+Pullout	Yes				L	L				2+HOV	48	15		63				2+HOV	63		**50**	113
Broadway																									
	On-ramp	No	1		Yes	2	Yes	M	L				2	24	8		32				2	32		**50**	82
Poplar Avenue	Buttonhook																								
	On-ramp	No	1		Yes	1		H	L		yes		2	**6**			6	yes	yes	yes	2+HOV	6		0	6
3rd Avenue	Full Cloverleaf/CD Road																								
	Loop On-ramp	Yes on CD	1					L	L				1	25			25				1	25		**50**	75
	Diagonal On-ramp	Yes	2					H	L				2	25	15		40				2	40		**50**	90
Junction Route 92	Multi-Level System Interchange																								
	Loop On-ramp	No	1										1	36			36								0
	Fashion Island On-ramp	N	1					H	H	yes			1	42			42	yes		yes	1	**84**		0	84
	Diagonal On-ramp	No	1										1	70											
E. Hillsdale Boulevard	Full Cloverleaf/CD Road																								
	Loop On-ramp	Yes	1	Yes				M	L				1	32	6		38		yes		2	**76**		0	76
	Diagonal On-ramp	Yes	1	Yes				L	L				1	55	5		60				1	60		**50**	110
Ralston/Harbor	Full Cloverleaf/CD Road																								
	Loop On-ramp	No	1					L	M								0								0
	Diagonal On-ramp	No	1					L	L								0								0
	Harbor On-ramp	No	1		Yes	1		M	L								0								0
	CD road entrance	No	1		Yes	2+HOV	Yes	M	L				2+HOV	104			104				2+HOV	104		0	104
Holly/Brittan	Full Cloverleaf/CD Road																								
	CD road entrance	Yes	2					L	L				2	119			119				2	119		**50**	169
Brittan Avenue	Isolated On-ramp																								
	On-ramp	Yes	2	Yes				L	L				2	32	20		52				2	52		**58**	110
Whipple Avenue	Partial Cloverleaf																								
	Loop On-ramp	No	1		Yes	1		L	M				1	21			21				1	21		**50**	71
	Diagonal On-ramp	No	2		Yes	2+HOV		M	M				2+HOV	40	3		43				2+HOV	43		**50**	93
Woodside Road / Seaport Boulevard																									
	On-ramp	No	1		Yes	2+HOV		H	H				2+HOV	90			90			yes	2+HOV	**180**		0	180
Marsh Road	Partial Cloverleaf																								
	Loop On-ramp	Yes	1					L	L				1	13	13		26				1	26		**50**	76
	Diagonal On-ramp	Yes	2					M	M	yes			2	58	10		68	yes		yes	2+HOV	**136**		0	136
Willow Road	Full Cloverleaf																								
	Loop On-ramp	No	1		Yes	1+HOV		L	M				1+HOV	16			16			yes	1+HOV	**32**		0	32
	Diagonal On-ramp	No	1		Yes	1+HOV		L	L				1+HOV	21			21				1+HOV	21		**50**	71
University Avenue	Buttonhook																								
	On-ramp	Yes	2		Yes	2	Yes	L	L				2	36	10		46				2	46		**50**	96

Table 4-1 On-Ramp Geometric Assessment Summary

		Existing Configuration			Planned/Programmed Improvements			Assessment for Widening		Scenario 1								Scenario 2							
										Modification				Queue Storage				Modification				Queue Storage			
Interchange Name	Interchange Type/On-ramp	Metered?	Lanes*	Dedicated Access	Metered?	Lanes*	Dedicated Access	Thru	Length	HOV	Thru	Storage	Lanes*	Ramp	Access	Spillover	Total	HOV	Thru	Storage	Lanes*	Ramp	Access	Spillover	Total
NORTHBOUND I-280																									
Junction Route 380	System Interchange																								
Sneath Lane																									
	On-ramp	Yes	2	Yes				M	M				2	47	4		51	yes		yes	2+HOV	**102**		0	102
Avalon Drive																									
Westborough Boulevard																									
	Loop On-ramp	Yes	1	Yes				L	L				1	26			26				1	26		**15**	41
	Diagonal On-ramp	Yes	1+HOV	Yes				L	L				1+HOV	67	13		80				1+HOV	80		0	80
Hickey Boulevard	Diamond																								
	Diagonal On-ramp	Yes	1					H	H	yes			1+HOV	31			31	yes		yes	1+HOV	31		0	31
Serramonte Boulevard																									
	On-ramp	Yes	2	Yes				L	L				2	56			56				2	56		0	56
Junction Route 1 South	Multi-Level																								
	On-ramp																								
Junipero Serra/ Washington Street																									
	On-ramp	No	1					M	H								0								0
Junipero Serra/ Route 1																									
Junipero Serra/ John Daly																									
SOUTHBOUND I-280																									
Junction Route 1 North/ John Daly Boulevard																									
	On-ramp	No	1	Yes				M	H				1	32	6		38				1	38		0	38
	SR-1 On-ramp																								
Sullivan Avenue /																									
Junction Route 1 South/Sullivan/ Serramonte	Multi-Level																								
	D-street/Sullivan On-ramp	Yes	1	Yes				L	L				1	113	10		123				1	123		0	123
	SR-1 On-ramp	No	1										1	44			44								
Hickey Boulevard																									
	On-ramp	No	1	Yes				L	L				1	26			26				1	26		0	26
Westborough Boulevard																									
	On-ramp	No	1	Yes				L	L				1	18			18				1	18		0	18
Avalon Drive																									
	On-ramp	No	1	Yes				M	H				1	13	5		18				1	18		0	18
Sneath Lane																									

Appendix C – Programmed/Planned Freeway Improvements

DKS *Associates*
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DRAFT

MEMORANDUM

TO: Peninsula Ramp Metering Study – Working Group
FROM: Terry Klim
DATE: July 11, 2003
SUBJECT: Draft Technical Memorandum #3 – Programmed/Planned Freeway Improvements P/A No. 03018-000x006

INTRODUCTION

This technical memorandum is one deliverable for Task 6 ("Prepare Base FREQ Models") of the Peninsula Corridor Ramp Metering Study. The objective of this study is to identify the potential impacts of ramp metering within the Peninsula Corridor. The study area includes US Highway 101 (US 101) within San Mateo County, and the northern section of and Interstate 280 (I-280), from I-380 to the San Francisco County line.

The first part of the project focuses on the freeway operational impacts of ramp metering. The goal of this series of steps is to determine if ramp metering can provide any significant operational benefits to the freeways in the study area. Specific issues to be addressed as part of the freeway operational analysis include:

- To what extent can ramp metering improve freeway operations?
- How will ramp metering and specifically queues from ramp meters, impact arterial operations?
- What are recommended meter operating parameters?

This part of the study is being accomplished by developing traffic simulation models of the freeway systems for two horizon years (2010 and 2020), adding ramp metering to the systems, and comparing the predicted performance with and without ramp metering. If it is determined that ramp metering may benefit some or all freeways, the second part of the project will focus on the potential impacts to the arterial street system throughout the study network.

This memorandum describes a set of the improvements that are programmed or planned for the study freeway segments. Typical improvements include the addition of auxiliary, reconfiguration of interchanges, and ramp modifications. The improvements described in this memo are to be incorporated into base 2010 and 2020 freeway simulation (FREQ) models.

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INFORMATION SOURCES

This listing of programmed and planned improvements presented in this memo were derived from a number of sources including:

- San Mateo County Transportation Authority Auxiliary Lane Program Plan – The Transportation Authority has undertaken an extensive auxiliary lane program for US 101. This program involves the construction of auxiliary lanes between all interchanges on US 101 through San Mateo County, as well as related interchange improvements. Interchange improvements include converting interchanges to a partial cloverleaf design, modifying individual ramps, and installing ramp meter equipment.
- Caltrans Design Plans – A number of programmed improvements, including those related to the Auxiliary Lane Program, are in the design and early construction stages. Specific details regarding these improvements were derived from a review of available design plans provided by Caltrans.
- Input from Working Group Members – Through discussions with individual Working Group members, additional background and insight was gathered.

LISTING OF IMPROVEMENT PROJECTS

The programmed and planned freeway network improvement projects for the study area are summarized in Table 1. In addition to a description of each project, this table also indicates the expected timeframe for completion of each improvement. This information is necessary to determine which model years each improvement should be included in. These same improvements are also highlighted in Figure 1.

In addition to these programmed and planned projects, a number of projects have recently been completed in the corridor. These include:

- Construction of the northbound auxiliary lane from Ralston to Hillsdale and related ramp modifications;
- Reconfiguration of San Bruno, SFO and Millbrae ramps; and
- Reconfiguration of the University Avenue interchange ramps (Phases 1 and 2).

These recent improvements are reflected in the base year FREQ model.

Table 1
Programmed and Planned Freeway Improvement Projects

Project	Description	Implementation Timeframe 2010	Implementation Timeframe 2020
Auxiliary Lanes -- Ralston to Marsh	(a) Add northbound and southbound auxiliary lanes from Ralston to Marsh Road (b) Holly (NB) – add HOV priority lanes; install ramp meters (c) Whipple (NB) – modify loop on-ramp (2 lanes); reconfigure merges to combine loop and diagonal; install ramp meters. (d) Woodside (NB) – add HOV priority lanes; install ramp meters. (e) Ralston/Harbor (SB) – reconfigure off-ramp to handle auxiliary lane; modify CD on-ramp (2 + HOV); install ramp meter at CD on-ramp. (f) Holly (SB) – Reconstruct off-ramp to handle auxiliary lane. (g) Whipple (SB)– modify diagonal on-ramp (2+HOV); install ramp meters. (h) Woodside (SB) – modify on-ramp (2+HOV); install ramp meters	X	
Auxiliary Lanes -- Millbrae to 3rd Avenue	(a) Add northbound and southbound auxiliary lanes from Millbrae and 3rd Street (b) Peninsula Avenue (NB) – widen on-ramp to 2 lanes; install ramp meters. (c) Anza Blvd (NB) - install meters	X	
Auxiliary Lanes -- Hillsdale to Ralston Blvd	(a) Add northbound and southbound auxiliary lanes from Hillsdale to Ralston (b) Ralston Avenue (NB) -- install ramp meters	X	
Auxiliary Lanes -- Sierra Point/Marina to SF County Line	(a) Add northbound and southbound auxiliary lanes from Sierra Point/Marina to SF County Line (b) Harney (NB) – widen off-ramp (2 lanes) (c) Harney (SB) – modify on-ramp (2 lanes); install meter (d) Sierra Point (NB) – add HOV priority lane; install meter		X
Auxiliary Lanes -- Marsh to Santa Clara County Line	Long term project; assume addition of northbound and southbound auxiliary lanes between Marsh and the Santa Clara County Line.		X
University Avenue Interchange -- Phase 3	Reconstruct SB off-ramp to connect directly to University	X	
Willow Road Interchange Project	(a) Convert NB ramps to parclo (b) Convert SB ramps to parclo		X
Ralston Avenue Interchange (Oracle Project)	(a) Convert NB ramps to parclo; eliminate CD road; modify diagonal on-ramp (2+HOV) (b) Convert SB ramps to parclo	X	
Broadway Interchange	(a) Reconstruct NB ramps -- Change diagonal and hook off ramp to standard off-ramp at new intersection; modify diagonal on-ramp (2+HOV); install ramp meters. (b) Reconstruct SB ramps -- Convert to diamond; modify diagonal on-ramp (2 lanes)	X	
Terrabay Hook On-Ramps (Oyster Point)	(a) Add SB hook on-ramp; install ramp meter (1 + HOV) (b) Modify Bayshore off-ramp	X	

Source: DKS Associates, 2003

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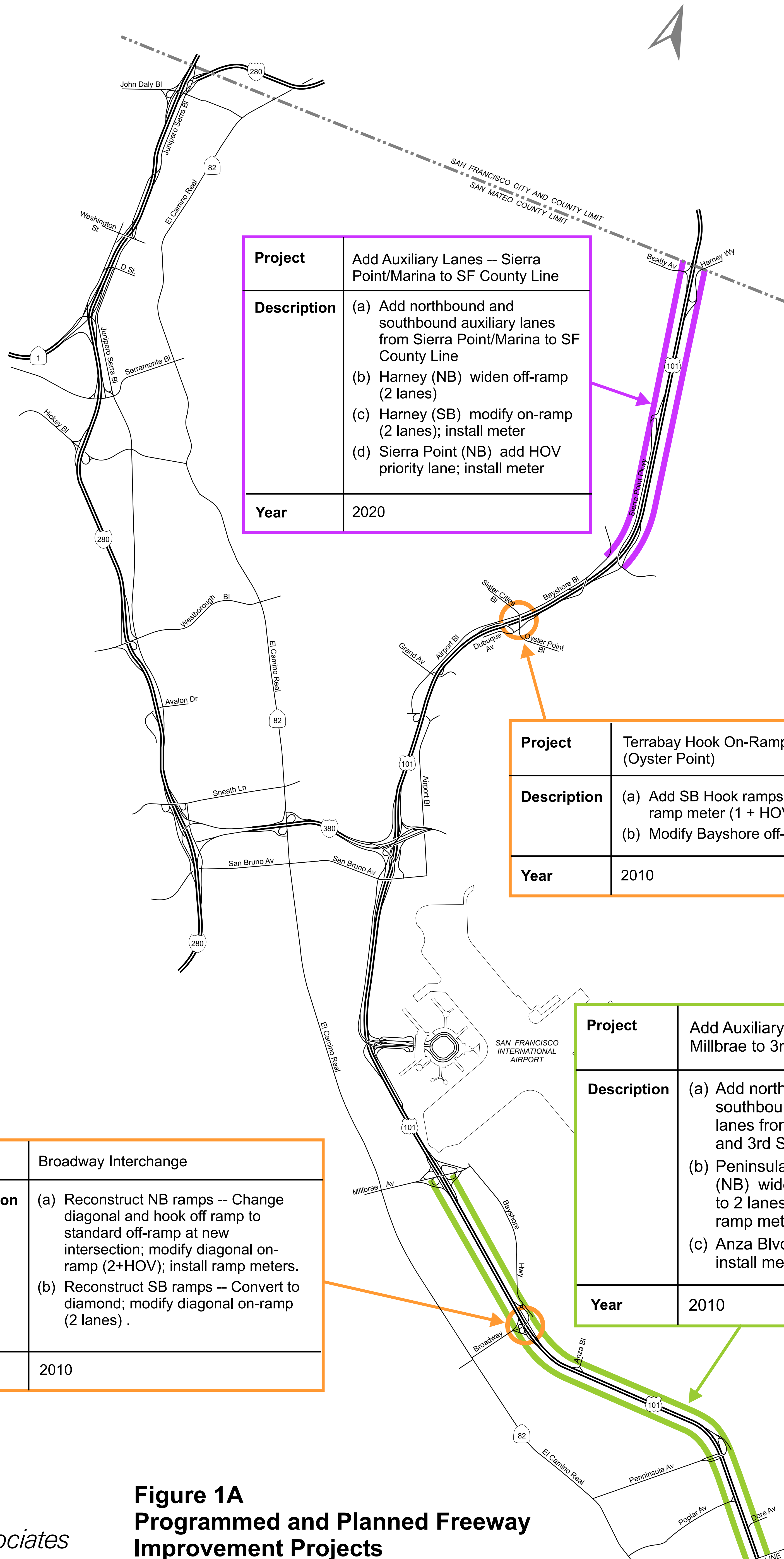

Project	Add Auxiliary Lanes -- Sierra Point/Marina to SF County Line
Description	(a) Add northbound and southbound auxiliary lanes from Sierra Point/Marina to SF County Line (b) Harney (NB) widen off-ramp (2 lanes) (c) Harney (SB) modify on-ramp (2 lanes); install meter (d) Sierra Point (NB) add HOV priority lane; install meter
Year	2020

Project	Terrabay Hook On-Ramps (Oyster Point)
Description	(a) Add SB Hook ramps. Install ramp meter (1 + HOV) (b) Modify Bayshore off- ramp
Year	2010

Project	Add Auxiliary Lanes -- Millbrae to 3rd Avenue
Description	(a) Add northbound and southbound auxiliary lanes from Millbrae and 3rd Street (b) Peninsula Avenue (NB) widen on-ramp to 2 lanes; install ramp meters. (c) Anza Blvd (NB) - install meters
Year	2010

Project	Broadway Interchange
Description	(a) Reconstruct NB ramps -- Change diagonal and hook off ramp to standard off-ramp at new intersection; modify diagonal on-ramp (2+HOV); install ramp meters. (b) Reconstruct SB ramps -- Convert to diamond; modify diagonal on-ramp (2 lanes) .
Year	2010

Figure 1A
Programmed and Planned Freeway Improvement Projects

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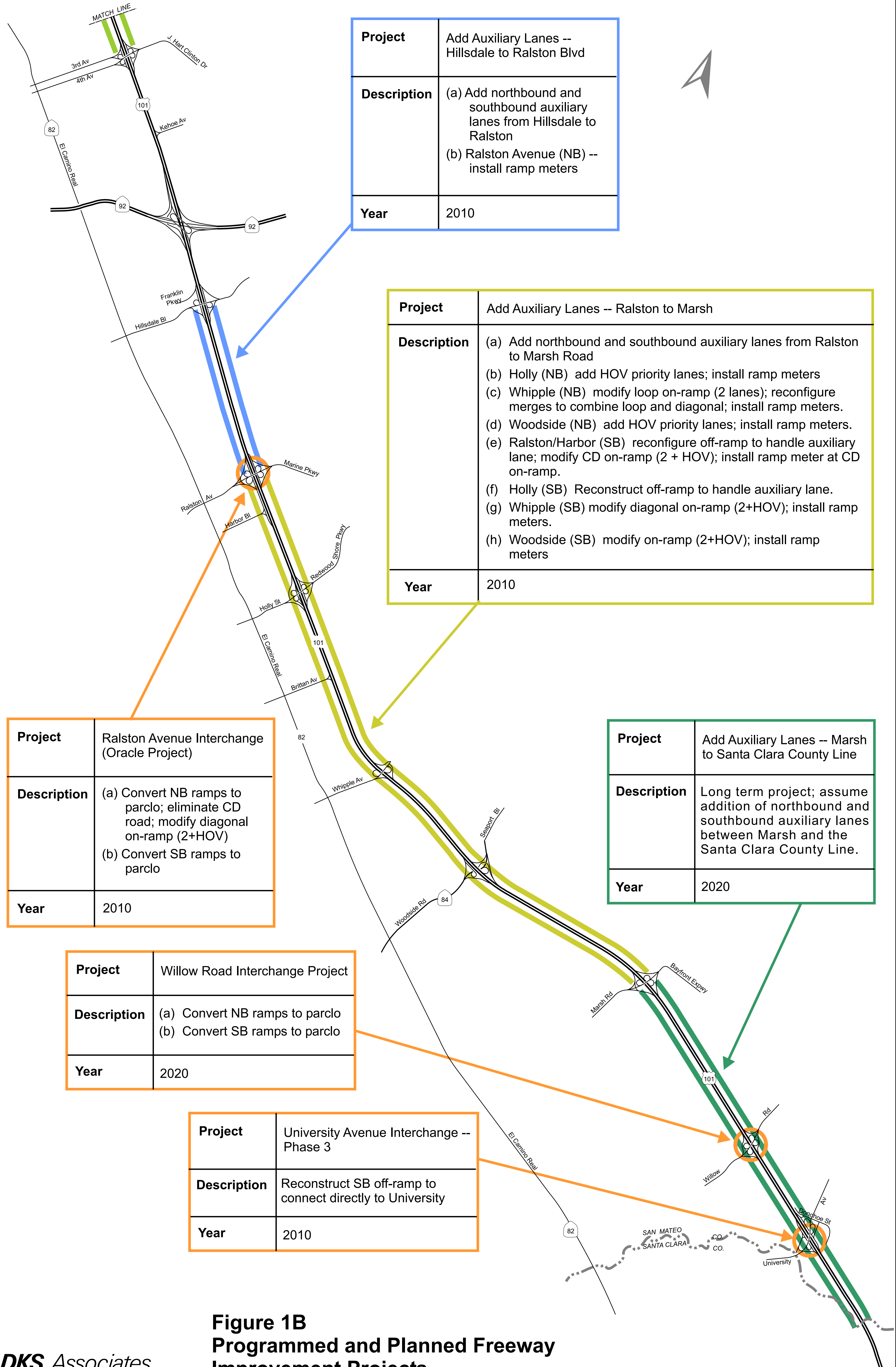

Project	Add Auxiliary Lanes -- Hillsdale to Ralston Blvd
Description	(a) Add northbound and southbound auxiliary lanes from Hillsdale to Ralston (b) Ralston Avenue (NB) -- install ramp meters
Year	2010

Project	Add Auxiliary Lanes -- Ralston to Marsh
Description	(a) Add northbound and southbound auxiliary lanes from Ralston to Marsh Road (b) Holly (NB) add HOV priority lanes; install ramp meters (c) Whipple (NB) modify loop on-ramp (2 lanes); reconfigure merges to combine loop and diagonal; install ramp meters. (d) Woodside (NB) add HOV priority lanes; install ramp meters. (e) Ralston/Harbor (SB) reconfigure off-ramp to handle auxiliary lane; modify CD on-ramp (2 + HOV); install ramp meter at CD on-ramp. (f) Holly (SB) Reconstruct off-ramp to handle auxiliary lane. (g) Whipple (SB) modify diagonal on-ramp (2+HOV); install ramp meters. (h) Woodside (SB) modify on-ramp (2+HOV); install ramp meters
Year	2010

Project	Ralston Avenue Interchange (Oracle Project)
Description	(a) Convert NB ramps to parclo; eliminate CD road; modify diagonal on-ramp (2+HOV) (b) Convert SB ramps to parclo
Year	2010

Project	Add Auxiliary Lanes -- Marsh to Santa Clara County Line
Description	Long term project; assume addition of northbound and southbound auxiliary lanes between Marsh and the Santa Clara County Line.
Year	2020

Project	Willow Road Interchange Project
Description	(a) Convert NB ramps to parclo (b) Convert SB ramps to parclo
Year	2020

Project	University Avenue Interchange -- Phase 3
Description	Reconstruct SB off-ramp to connect directly to University
Year	2010

Figure 1B
Programmed and Planned Freeway Improvement Projects

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Appendix D – Future Year Base Traffic Demand Forecasts

DKS *Associates*
TRANSPORTATION SOLUTIONS

MEMORANDUM

TO:	Peninsula Ramp Metering Study – Working Group
FROM:	Terry Klim
DATE:	July 11, 2003
SUBJECT:	Base Traffic Demand Forecasts — P/A No. 03018-000x005

This technical memorandum is one deliverable for the Peninsula Corridor Ramp Metering Study. The objective of this study is to identify the potential impacts of ramp metering within the Peninsula Corridor. The study area includes US Highway 101 (US 101) within San Mateo County, and the northern section of and Interstate 280 (I-280), from I-380 to the San Francisco County line.

This study is being accomplished by developing traffic simulation models of the freeway systems for two horizon years (2010 and 2020), adding ramp metering to the systems, and comparing the predicted performance with and without ramp metering.

As part of creating these models, it is necessary to develop future year demand forecasts for each ramp included in the model network. The process for developing these forecasts combined existing ramp volume counts with forecasted growth rates derived from the San Mateo countywide EMME/2 travel demand forecasting model. The travel demand model datasets used in this process included those for the following years and peak periods:

- 2000 AM and PM;
- 2010 AM and PM; and
- 2020 AM and PM.

In reviewing the travel demand model outputs, it was discovered that as a result of congestion on the freeway, the model would occasionally assign trips to an off-ramp then an on-ramp at the same interchange. In most cases where this occurred, the specific movements are actually prohibited by physical features of the roadway system. To correct this situation, additional turn penalties or prohibitions were coded in the travel demand network, and the trips re-assigned.

It was also noted that the growth pattern (from 2000 to 2010, and 2010 to 2020) varied significantly for individual links. In some cases, the travel demand model predicts excessive growth for one time step, and very little growth or even a decrease in demand for the other time step. This is in part typical of most travel demand models, especially when demands on a link approach or exceed the model capacity. Because of this, it was deemed inappropriate to use the growth factors or rates of individual ramps.

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Thus, the approach used for this study involved aggregating geographic sets of ramps and calculating an overall growth rate for those ramps. The resulting rates for each grouping (separate rates were developed for each time period and direction) were then applied to the existing counts to determine the forecasted traffic demand. For example, all northbound on-ramps from University Avenue to Hillsdale were combined, and a single growth rate or factor for Year 2000 to Year 2020 was determined. The Year 2010 growth rate was assumed to be half of the Year 2020 factor. Similarly, aggregated factors were developed for the northbound off-ramps in this segment, the southbound on-ramps, etc. As an exception to this approach, the SR 92 ramps were kept separate, and individual rates developed for these ramps. The resulting growth rates are presented in Tables 1 through 7 below.

These growth rates were applied to existing counts coded into the base year FREQ model to create the demand datasets for the 2010 and 2020 models. As part of this process, a reasonableness check was conducted comparing the forecasted demand with roadway capacity. Where appropriate, minor adjustments were made to the growth rates for individual locations. In many instances, this adjustment involved "spreading" the growth more evenly over the peak period so that the peak hour would not significantly exceed capacity, but so the total growth in volume over the entire period would remain the same.

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Table 1
Comparison of Peak Period On-Ramp Demand, US 101 – Northbound – AM

		Model Forecasts			Forecasted Change		
Interchange	**Counts**	**2000**	**2010**	**2020**	**2000 to 2010**	**2010 to 2020**	**2000 to 2020**
Mainline US 101							
Mainline		25,760	33,780	35,920	8,020	2,140	10,160
University Avenue							
Loop on-ramp	960	270	200	250	(70)	50	(20)
Diagonal on-ramp	1,060	1,370	2,450	4,200	1,080	1,750	2,830
Willow Road							
Diagonal on-ramp	1,210	2,110	2,760	3,760	650	1,000	1,650
Loop on-ramp	1,020	1,250	1,700	2,040	450	340	790
Marsh Road							
Loop on-ramp	1,310	240	510	1,200	270	690	960
Diagonal on-ramp	4,090	8,730	9,630	10,040	900	410	1,310
Woodside Road / Seaport Boulevard							
Loop on-ramp	3,410	2,590	4,850	5,260	2,260	410	2,670
Diagonal on-ramp	880	430	1,430	3,020	1,000	1,590	2,590
Whipple Avenue							
Loop on-ramp	2,920	5,490	7,770	8,380	2,280	610	2,890
Diagonal on-ramp	200	380	1,970	4,030	1,590	2,060	3,650
Holly Street							
Loop on-ramp	2,550	2,730	3,570	6,430	840	2,860	3,700
Diagonal on-ramp	890	340	4,250	4,560	3,910	310	4,220
Ralston Avenue							
Loop on-ramp	1,690	70	390	790	320	400	720
Diagonal on-ramp	1,740	4,750	8,500	9,180	3,750	680	4,430
E. Hillsdale Boulevard							
Loop on-ramp	2,540	1,940	2,500	2,920	560	420	980
Diagonal on-ramp	2,050	1,480	1,890	1,530	410	(360)	50
Junction Route 92							
Loop on-ramp	1,710	1,290	2,240	2,580	950	340	1,290
Diagonal on-ramp	2,810	4,930	4,430	5,120	(500)	690	190
Diagonal on-ramp		*1,490*	*980*	*1,510*	*(510)*	*530*	*20*
Diagonal on-ramp from Fashion Island Blvd		*3,440*	*3,450*	*3,610*	*10*	*160*	*170*
Kehoe Avenue							
Hook on-ramp	940	690	1,850	1,820	1,160	(30)	1,130
3rd Avenue							
Loop on-ramp	1,830	510	2,510	2,560	2,000	50	2,050
Diagonal on-ramp	1,270	5,310	6,860	7,480	1,550	620	2,170

Table 1 (Continued)
Comparison of Peak Period On-Ramp Demand, US 101 – Northbound – AM

		Model Forecasts			Forecasted Change		
Interchange Name	**Counts**	**2000**	**2010**	**2020**	**2000 to 2010**	**2000 to 2020**	**2010 to 2020**
Peninsula Avenue							
Hook on-ramp	1,990	1,380	1,520	2,050	140	670	530
Anza Boulevard							
Hook on-ramp	400	720	590	960	(130)	240	370
Broadway							
Hook on-ramp	2,730	2,340	4,560	7,020	2,220	4,680	2,460
Millbrae Avenue/San Francisco Airport							
Millbrae On-ramp	3,110	10,680	5,470	6,330	(5,210)	(4,350)	860
Diagonal On-ramp		*2,370*					
Loop On-ramp		*8,310*					
Diagonal on-ramp			*5,470*	*6,330*			
Airport on-ramp	1,680	1,280	1,440	2,340	160	1,060	900
On-ramp from Terminal		*100*	*90*	*110*	*(10)*	*10*	*20*
On-ramp from Terminal		*1,180*	*1,350*	*2,230*	*170*	*1,050*	*880*
Junction I-380							
On-ramp from San Bruno	1,600	2,740	5,010	5,850	2,270	3,110	840
I-380/N. Access On-ramp	7,860	4,430	7,720	10,090	3,290	5,660	2,370
From I-380 EB		*4,350*	*6,280*	*7,960*	*1,930*	*3,610*	*1,680*
From N. Access		*10*	*20*	*70*	*10*	*60*	*50*
From Airport Blvd		*70*	*1,420*	*2,060*	*1,350*	*1,990*	*640*
Produce/Airport Boulevards							
On-ramp	1,430	2,670	1,160	1,360	(1,510)	(1,310)	200
Grand Avenue							
On-ramp	1,690	2,170	2,880	3,810	710	1,640	930
Oyster Point Boulevard							
On-ramp	1,940	4,410	7,730	6,560	3,320	2,150	(1,170)
Bayshore Boulevard/Sierra Point							
On-ramp	210	110	250	470	140	360	220

Table 2
Comparison of Peak Period On-Ramp Demand, I-280 – Northbound – AM

Interchange	Counts	Model Forecasts 2000	2010	2020	Forecasted Change 2000 to 2010	2010 to 2020	2000 to 2020
Mainline I-280							
Mainline		23,690	22,340	22,450	(1,350)	110	(1,240)
Junction I-380							
On-ramp	1,790	9,330	12,140	12,700	2,810	560	3,370
Sneath Lane							
On-ramp	2,080	3,040	2,760	4,480	(280)	1,720	1,440
Westborough Boulevard							
Loop on-ramp	1,450	780	510	490	(270)	(20)	(290)
Diagonal on-ramp	1,630	230	460	970	230	510	740
Hickey Boulevard							
Diagonal on-ramp	1,590	1,270	2,200	3,580	930	1,380	2,310
Serramonte Boulevard							
On-ramp	2,350	4,380	4,170	4,740	(210)	570	360
Junction Route 1 South							
On-ramp	1,760	6,600	7,690	8,120	1,090	430	1,520
Sullivan Avenue / Washington Street							
On-ramp	3,550	4,800	5,540	7,190	740	1,650	2,390

Table 3
Comparison of Peak Period On-Ramp Demand, US 101 – Southbound – AM

		Model Forecasts			Forecasted Change		
Interchange Name	**Counts**	**2000**	**2010**	**2020**	**2000 to 2010**	**2010 to 2020**	**2000 to 2020**
Mainline US 101							
Mainline		35,230	39,160	40,280	3,930	1,120	5,050
Harney Way							
Diagonal on-ramp	930	460	610	650	150	40	190
Bayshore Boulevard/Sierra Point							
On-ramp	960	1,660	2,740	2,620	1,080	(120)	960
Oyster Point Boulevard							
On-ramp	5,100	1,650	1,120	1,540	(530)	420	(110)
Produce/Airport Boulevards							
On-ramp	3,430	13,480	11,900	12,100	(1,580)	200	(1,380)
Junction I-380							
Northern Access Rd on-ramp	520	250	5,650	2,580	5,400	(3,070)	2,330
EB 380 on-ramp	19,650	10,040	9,790	9,870	(250)	80	(170)
San Francisco Airport							
San Bruno on-ramp	3,180	5,880	4,710	4,730	(1,170)	20	(1,150)
Airport on-ramps	1,610	7,500	10,360	11,170	2,860	810	3,670
2nd on-ramp		*370*	*1,660*	*1,850*	*1,290*	*190*	*1,480*
3rd on-ramp		*4,320*	*5,510*	*5,810*	*1,190*	*300*	*1,490*
4th on-ramp		*2,810*	*3,190*	*3,510*	*380*	*320*	*700*
Millbrae Avenue							
Loop on-ramp	540	1,830	170	1,010	(1,660)	840	(820)
Diagonal on-ramp	1,720	940	3,930	2,720	2,990	(1,210)	1,780
Broadway							
On-ramp	4,230	7,840	9,700	9,020	1,860	(680)	1,180
Poplar Avenue							
On-ramp	2,690	6,780	7,430	6,540	650	(890)	(240)
3rd Avenue							
Loop on-ramp	960	3,380	2,190	2,740	(1,190)	550	(640)
Diagonal on-ramp	4,240	3,930	1,990	2,130	(1,940)	140	(1,800)
Junction Route 92							
Loop on-ramp	1,260	6,130	6,890	7,340	760	450	1,210
Fashion Island on-ramp	1,640	3,110	5,390	6,490	2,280	1,100	3,380
Diagonal on-ramp	3,680	2,700	580	440	(2,120)	(140)	(2,260)
E. H Full Cloverleaf/CD Road							
Loop on-ramp	2,920	6,740	8,210	8,490	1,470	280	1,750
Diagonal on-ramp	1,230	3,060	5,450	5,610	2,390	160	2,550
Ralston Avenue							
Loop on-ramp	1,620	300	270	380	(30)	110	80
Diagonal on-ramp	1,820	10,130	10,590	11,080	460	490	950
Harbor on-ramp	3,130	270	1,000	1,040	730	40	770

Table 3 (Continued)
Comparison of Peak Period On-Ramp Demand, US 101 – Southbound – AM

Interchange Name	Counts	Model Forecasts 2000	2010	2020	Forecasted Change 2000 to 2010	2010 to 2020	2000 to 2020
Holly Street							
CD road entrance	2,180	9,140	13,630	11,940	4,490	(1,690)	2,800
Loop on-ramp		*4,430*	*7,650*	*6,570*	*3,220*	*(1,080)*	*2,140*
Diagonal on-ramp		*4,710*	*5,980*	*5,370*	*1,270*	*(610)*	*660*
Brittan Avenue							
On-ramp	1,310	8,370	9,520	10,490	1,150	970	2,120
Whipple Avenue							
Loop on-ramp	210	20	40	40	20	-	20
Diagonal on-ramp	2,180	1,640	2,460	2,260	820	(200)	620
Woodside Road / Seaport Boulevard							
On-ramp	2,990	8,440	10,420	11,680	1,980	1,260	3,240
Marsh Road							
Loop on-ramp	1,130	750	750	20	-	(730)	(730)
Diagonal on-ramp	1,570	600	1,340	1,300	740	(40)	700
Willow Road							
Loop On-ramp	1,320	6,280	7,180	7,710	900	530	1,430
Diagonal On-ramp	1,660	2,620	4,650	4,140	2,030	(510)	1,520
University Avenue							
On-ramp	3,770	8,400	11,190	11,780	2,790	590	3,380

Table 4
Comparison of Peak Period On-Ramp Demand, I-280 – Southbound – AM

		Model Forecasts			Forecasted Change		
Interchange Name	**Counts**	**2000**	**2010**	**2020**	**2000 to 2010**	**2010 to 2020**	**2000 to 2020**
Mainline I-280							
Mainline		27,580	30,350	28,860	2,770	(1,490)	1,280
Junction Route 1 North/ John Daly Boulevard							
on-ramp from SR 1	10,130	14,290	16,120	15,010	1,830	(1,110)	720
on-ramp from John Daly Blvd	4,230	5,620	5,290	7,570	(330)	2,280	1,950
Junction Route 1 South							
SR 1 on-ramp	2,700	1,740	2,640	2,770	900	130	1,030
Sullivan On-ramp	2,600	3,780	4,120	3,620	340	(500)	(160)
Hickey Boulevard							
On-ramp	2,270	4,230	4,410	4,880	180	470	650
Westborough Boulevard							
On-ramp	3,370	7,220	7,770	7,390	550	(380)	170
Avalon Drive							
On-ramp	2,180	11,040	12,080	11,900	1,040	(180)	860

Table 5
Comparison of Peak Period On-Ramp Demand, US 101 – Northbound – PM

Interchange	Counts	Model Forecasts 2000	2010	2020	Forecasted Change 2000 to 2010	2010 to 2020	2000 to 2020
Mainline US 101							
Mainline		35,330	40,900	40,640	5,570	(260)	5,310
University Avenue							
Loop on-ramp	800	1,010	1,530	1,510	520	(20)	500
Diagonal on-ramp	750	440	2,910	4,150	2,470	1,240	3,710
Willow Road							
Diagonal on-ramp	1,320	930	3,630	2,800	2,700	(830)	1,870
Loop on-ramp	600	2,300	2,960	2,160	660	(800)	(140)
Marsh Road							
Loop on-ramp	1,240	80	170	230	90	60	150
Diagonal on-ramp	2,720	9,770	10,750	10,730	980	(20)	960
Woodside Road / Seaport Boulevard							
Loop on-ramp	2,920	2,910	5,800	4,870	2,890	(930)	1,960
Diagonal on-ramp	1,340	570	660	1,470	90	810	900
Whipple Avenue							
Loop on-ramp	3,330	6,820	8,770	7,330	1,950	(1,440)	510
Diagonal on-ramp	460	640	1,840	2,770	1,200	930	2,130
Holly Street							
Loop on-ramp	2,350	6,360	7,520	6,270	1,160	(1,250)	(90)
Diagonal on-ramp	1,440	470	5,140	5,560	4,670	420	5,090
Ralston Avenue							
Loop on-ramp	1,900	1,330	800	730	(530)	(70)	(600)
Diagonal on-ramp	2,510	6,170	8,500	9,850	2,330	1,350	3,680
E. Hillsdale Boulevard							
Loop on-ramp	2,270	3,550	3,280	3,160	(270)	(120)	(390)
Diagonal on-ramp	1,440	1,670	1,720	2,090	50	370	420
Junction Route 92							
Loop on-ramp	2,520	2,860	4,130	4,160	1,270	30	1,300
Diagonal on-ramp	5,940	7,670	6,700	6,310	(970)	(390)	(1,360)
Diagonal on-ramp		*5,080*	*4,560*	*3,380*	*(520)*	*(1,180)*	*(1,700)*
Diagonal on-ramp from Fashion Island Blvd		*2,590*	*2,140*	*2,930*	*(450)*	*790*	*340*
Kehoe Avenue							
Hook on-ramp	500	570	1,130	1,390	560	260	820
3rd Avenue							
Loop on-ramp	2,270	1,830	3,600	3,340	1,770	(260)	1,510
Diagonal on-ramp	1,720	6,490	7,210	8,310	720	1,100	1,820

Table 5 (Continued)
Comparison of Peak Period On-Ramp Demand, US 101 – Northbound – PM

		Model Forecasts			Forecasted Change		
Interchange Name	**Counts**	**2000**	**2010**	**2020**	**2000 to 2010**	**2010 to 2020**	**2000 to 2020**
Peninsula Avenue							
Hook on-ramp	1,630	630	2,310	4,820	1,680	2,510	4,190
Anza Boulevard							
Hook on-ramp	1,160	790	1,990	2,420	1,200	430	1,630
Broadway							
Hook on-ramp	2,760	5,300	5,880	5,610	580	(270)	310
Millbrae Avenue/San Francisco Airport							
Millbrae On-ramp	4,250	16,700	7,370	6,750	(9,330)	(620)	(9,950)
Diagonal On-ramp		*6,350*					
Loop On-ramp		*10,350*					
Diagonal on-ramp			*7,370*	*6,750*			
Airport on-ramp	1,960	630	2,290	2,220	1,660	(70)	1,590
On-ramp from Terminal		*80*	*80*	*90*	-	*10*	*10*
On-ramp from Terminal		*550*	*2,210*	*2,130*	*1,660*	*(80)*	*1,580*
Junction I-380							
On-ramp from San Bruno	2,170	4,520	6,350	6,470	1,830	120	1,950
I-380/N. Access On-ramp	5,110	5,690	8,890	8,330	3,200	(560)	2,640
From I-380 EB		*3,280*	*6,260*	*4,470*	*2,980*	*(1,790)*	*1,190*
From N. Access		*80*	*70*	*60*	*(10)*	*(10)*	*(20)*
From Airport Blvd		*2,330*	*2,560*	*3,800*	*230*	*1,240*	*1,470*
Produce/Airport Boulevards							
On-ramp	1,430	3,680	2,170	2,310	(1,510)	140	(1,370)
Grand Avenue							
On-ramp	2,290	1,550	1,600	1,670	50	70	120
Oyster Point Boulevard							
On-ramp	3,380	5,950	6,800	7,480	850	680	1,530
Bayshore Boulevard/Sierra Point							
On-ramp	510	260	440	530	180	90	270

Table 6
Comparison of Peak Period On-Ramp Demand, I-280 – Northbound – PM

Interchange	Counts	Model Forecasts 2000	2010	2020	Forecasted Change 2000 to 2010	2010 to 2020	2000 to 2020
Mainline I-280							
Mainline		22,730	25,070	23,830	2,340	(1,240)	1,100
Junction I-380							
On-ramp	3,030	14,360	14,650	15,230	290	580	870
Sneath Lane							
On-ramp	5,230	5,030	4,210	7,200	(820)	2,990	2,170
Westborough Boulevard							
Loop on-ramp	880	80	70	60	(10)	(10)	(20)
Diagonal on-ramp	1,450	1,630	1,900	1,160	270	(740)	(470)
Hickey Boulevard							
Diagonal on-ramp	1,380	1,900	2,790	3,100	890	310	1,200
Serramonte Boulevard							
On-ramp	4,890	5,330	4,410	5,030	(920)	620	(300)
Junction Route 1 South							
On-ramp	3,630	8,200	7,840	7,690	(360)	(150)	(510)
Sullivan Avenue / Washington Street							
On-ramp	3,980	5,800	6,100	7,390	300	1,290	1,590

Table 7
Comparison of Peak Period On-Ramp Demand, US 101 – Southbound – PM

Interchange Name	Counts	Model Forecasts 2000	2010	2020	Forecasted Change 2000 to 2010	2010 to 2020	2000 to 2020
Mainline US 101							
Mainline		30,470	33,580	34,160	3,110	580	3,690
Harney Way							
Diagonal on-ramp	650	370	500	550	130	50	180
Bayshore Boulevard/Sierra Point							
On-ramp	1,130	750	1,480	2,430	730	950	1,680
Oyster Point Boulevard							
On-ramp	7,710	880	1,320	1,100	440	(220)	220
Produce/Airport Boulevards							
On-ramp	5,270	10,010	11,560	13,560	1,550	2,000	3,550
Junction I-380							
Northern Access Rd on-ramp	1,320	430	2,110	3,000	1,680	890	2,570
EB 380 on-ramp	11,400	9,470	9,280	10,640	(190)	1,360	1,170
San Francisco Airport							
San Bruno on-ramp	2,940	4,940	5,530	4,300	590	(1,230)	(640)
Airport on-ramps	1,580	4,070	8,150	10,020	4,080	1,870	5,950
2nd on-ramp		-	*80*	*1,000*	*80*	*920*	*1,000*
3rd on-ramp		*680*	*4,460*	*5,210*	*3,780*	*750*	*4,530*
4th on-ramp		*3,390*	*3,610*	*3,810*	*220*	*200*	*420*
Millbrae Avenue							
Loop on-ramp	520	1,050	2,050	2,140	1,000	90	1,090
Diagonal on-ramp	1,820	290	1,510	2,210	1,220	700	1,920
Broadway							
On-ramp	5,340	4,880	8,320	9,040	3,440	720	4,160
Poplar Avenue							
On-ramp	2,400	4,500	6,000	6,600	1,500	600	2,100
3rd Avenue							
Loop on-ramp	1,260	1,220	1,290	2,140	70	850	920
Diagonal on-ramp	2,880	4,830	3,330	3,190	(1,500)	(140)	(1,640)
Junction Route 92							
Loop on-ramp	1,370	4,520	5,020	5,430	500	410	910
Fashion Island on-ramp	1,060	1,590	4,540	6,140	2,950	1,600	4,550
Diagonal on-ramp	3,590	1,880	640	560	(1,240)	(80)	(1,320)
E. Hillsdale Boulevard							
Loop on-ramp	1,680	6,370	7,440	7,920	1,070	480	1,550
Diagonal on-ramp	1,060	840	4,560	5,630	3,720	1,070	4,790
Ralston Avenue							
Loop on-ramp	2,920	370	520	720	150	200	350
Diagonal on-ramp	1,140	6,970	9,370	10,430	2,400	1,060	3,460
Harbor on-ramp	3,230	540	970	1,900	430	930	1,360

Table 7 (Continued)
Comparison of Peak Period On-Ramp Demand, US 101 – Southbound – PM

Interchange Name	Counts	Model Forecasts 2000	2010	2020	Forecasted Change 2000 to 2010	2010 to 2020	2000 to 2020
Holly Street							
CD road entrance	2,300	5,990	10,960	14,200	4,970	3,240	8,210
Loop on-ramp		*4,260*	*5,720*	*6,880*	*1,460*	*1,160*	*2,620*
Diagonal on-ramp		*1,730*	*5,240*	*7,320*	*3,510*	*2,080*	*5,590*
Brittan Avenue							
On-ramp	960	5,660	8,120	10,390	2,460	2,270	4,730
Whipple Avenue							
Loop on-ramp	330	60	40	60	(20)	20	-
Diagonal on-ramp	2,300	760	2,350	2,310	1,590	(40)	1,550
Woodside Road / Seaport Boulevard							
On-ramp	3,440	7,270	9,900	11,210	2,630	1,310	3,940
Marsh Road							
Loop on-ramp	1,250	-	10	10	10	-	10
Diagonal on-ramp	1,890	180	180	240	-	60	60
Willow Road							
Loop On-ramp	2,950	2,890	3,240	4,080	350	840	1,190
Diagonal On-ramp	970	1,010	1,300	2,130	290	830	1,120
University Avenue							
On-ramp	2,010	2,940	5,380	7,380	2,440	2,000	4,440

Table 8
Comparison of Peak Period On-Ramp Demand, I-280 – Southbound – PM

Interchange	Counts	Model Forecasts 2000	2010	2020	Forecasted Change 2000 to 2010	2010 to 2020	2000 to 2020
Mainline I-280							
Mainline		24,820	27,460	28,030	2,640	570	3,210
Junction Route 1 North/ John Daly Boulevard							
On-ramp from SR 1	8,600	11,010	11,560	12,280	550	720	1,270
On-ramp from John Daly Blvd	5,310	3,480	4,620	4,970	1,140	350	1,490
Junction Route 1 South							
SR 1 on-ramp	1,530	1,160	2,060	1,830	900	(230)	670
Sullivan On-ramp	3,570	520	1,720	1,830	1,200	110	1,310
Hickey Boulevard							
On-ramp	2,630	1,090	1,210	3,390	120	2,180	2,300
Westborough Boulevard							
On-ramp	1,670	1,890	3,120	4,790	1,230	1,670	2,900
Avalon Drive							
On-ramp	1,410	6,780	9,380	11,600	2,600	2,220	4,820

Appendix E – Future Year "No Metering" Analysis Results

Peninsula Corridor Ramp Meeting Study: No-Metering Analysis Results - Final

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DATE: February 27, 2004

Introduction

This technical memorandum is the deliverable for Task 6 ("Develop Baseline Freeway Analysis Models (2010 and 2020 No-Metering Analysis)") for the Peninsula Corridor Ramp Metering Study. The objective of the Peninsula Corridor Ramp Metering Study is to assess the role of ramp metering for helping manage traffic within the Peninsula Corridor. The study area includes US Highway 101 (US 101) within San Mateo County, and the northern section of and Interstate 280 (I-280), from I-380 to the San Francisco County line.

The first part of the project focuses on the freeway operational impacts of ramp metering. The goal of this series of steps is to determine if ramp metering can provide any significant operational benefits to the freeways in the study area. This is being accomplished by developing traffic simulation models of the freeway systems for two horizon years (2010 and 2020), adding ramp metering to the systems, and comparing the predicted performance with and without ramp metering. If it is determined that ramp metering may benefit some or all freeways, the second part of the project will focus on the potential impacts to the arterial street system throughout the study network.

This memorandum describes the development of the existing conditions (2003) freeway simulation models (using the FREQ traffic analysis software) and the update of these models for Years 2010 and 2020.

Existing Conditions Coding

FREQ is a freeway corridor model, which allows for the coding of the freeway mainline and ramp entrance and exit points only. Additionally, FREQ allows for only one direction of the freeway to be coded for each file; therefore, one file was created for each direction of travel for each freeway.

Geometry

To code the existing conditions freeway simulation models, a field review was conducted to determine the number of lanes on the mainline freeways, the number of lanes merging or diverging from the freeway at each ramp location and the approximate spacing between interchanges and ramps. On-ramp data were coded using the information from Technical Memorandum No. 2 ("San Mateo Ramp Metering - On-Ramp Geometric Assessment "). The following information was collected for each on-ramp: the location of any existing metering equipment, the number of lanes (at the meter point and upstream), and the estimated storage capacity (number of cars).

Demand

Once the geometric data were coded in FREQ, demand data were entered. Each freeway and direction were analyzed during both the AM (6-10 AM) and PM peak periods (3-7 PM).

Existing traffic count data were evaluated and a table of mainline and ramp counts was produced for the study area. Existing traffic count data were provided by Caltrans (counts between 1999-2001) and from new tube counts (counted in 2003). The volumes were not adjusted for growth because historical growth rates have been relatively flat in the area.

Next, Caltrans data were used to determine the number of high occupancy vehicles (HOV). It was determined that HOVs were approximately 13% of the traffic stream. The HOV volume was then subtracted from the demand data to get volumes for analysis on non-HOV lanes only.

The hourly data were then broken into 15-minute data. The 15-minute data for any one hour were developed by splitting the hour into 15-minute time slices considering the hourly volume for the hour before and the hour after.

Since the data were collected over several years, the volumes did not balance internally. A scale factor was developed for each 15-minute period by dividing the on-ramp volumes by the off-ramp volumes. If this value was equal to one, the volume entering the freeway system would be equal to the volume exiting the freeway system. A value of one can typically be expected during periods with no congestion. During peak commute periods, it is to be expected that the scale factors will not be equal to one. Ideally, as demand and congestion increases over the peak period, more people will enter the freeway than exit, and the scale factor will be greater than one. As demand falls off and congestion decreases, the scale factor will decrease below one until the queued vehicles can exit the system. Typically, scale factors should range between 0.95 and 1.05 during the peak commute times. Figure 1 shows a typical scale factor pattern from I-280.

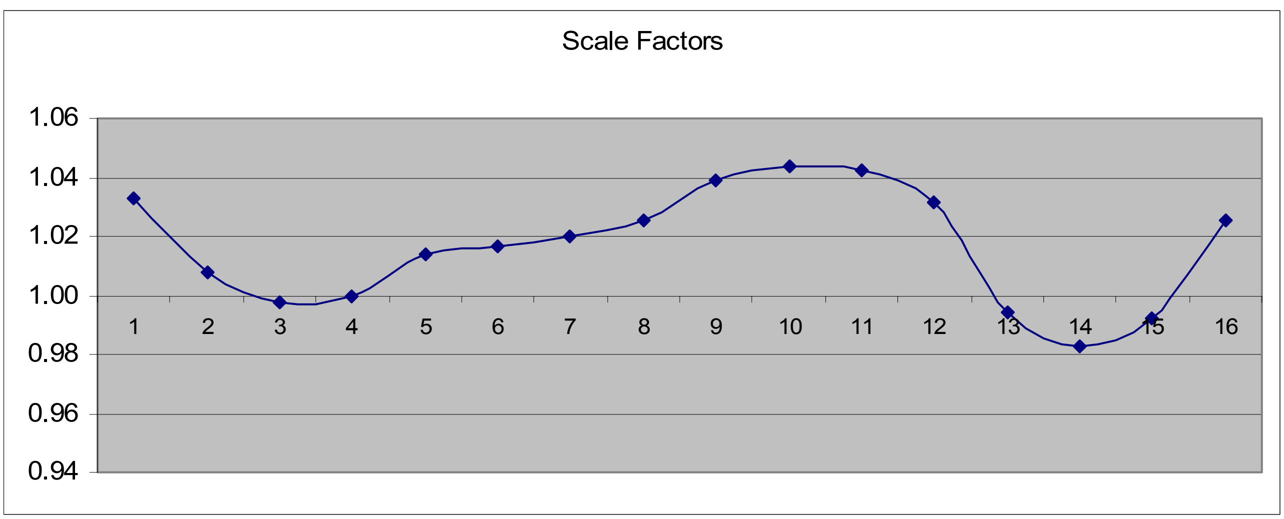

FIGURE 1. Typical Scale Factor Pattern during a Peak Commute Period

The scale factors were assessed for the analysis periods. Where the scale factors did not follow a logical peaking pattern or were lower/higher than the typical (0.95 /1.05), the following sources of data were consulted for adjusting the volumes:

- Flips from reverse direction (i.e. a northbound off-ramp during the AM peak will typically have similar volume to the southbound on-ramp during the PM peak).
- Data used for the previous project (1998)

Capacity

Capacity of each freeway segment was determined based on the following rules:

- Basic freeway segment: 2,100 vehicles per hour (vph)
- Mainline freeway lanes near collector-distributor (C-D) roads: 2,000 vph
- Auxiliary lane: 1,900 vph
- C-D lane: 1,600 vph
- HOV area (capacity reduced to reflect HOV weaving):
  - before heavy off-ramp or after heavy on-ramp: 1,900 vph
  - before or after other ramp areas: 2,000 vph

  (A heavy off- or on-ramp was defined as exceeding 1,000 vph.)

Existing Conditions Calibrated Model Results

The FREQ models were run and compared with travel time data (collected in 2003) and bottleneck locations. The models were considered calibrated when corridor travel times were within ten percent of field data. To further refine the existing models, a few capacity adjustments were made to better match existing travel times and bottleneck locations. Table 1 presents the comparison between the modeled and field travel time data. FREQ contour maps that illustrate the relative congestion patterns for each freeway/direction are provided at the back of this memo in Figures 2-5. Additional detail is provided in Appendix A (Existing Conditions Calibration PowerPoint Presentation).

2010 and 2020 Coding

To create the 2010 and 2020 FREQ models, the freeway/ramp geometry and demand data needed to be updated. The geometric coding was updated as described in Technical Memorandum #3 ("Programmed/Planned Freeway Improvements"). Figures 2 and 3 are a summary of the programmed and planned improvements. The demand data were updated based on output from the EMME/2 traffic demand model as documented in the technical memorandum titled, *"Base Traffic Demand Forecasts"*.

2010 and 2020 No-Metering Results

As before, travel time data and bottleneck locations were identified to establish the change in corridor conditions from the existing conditions analysis. The no-metering results indicate a significant increase in congestion. Corridor travel times generally increase substantially for US 101. For I-280, corridor travel times increase in both directions, but more notably in the southbound direction. Corridor travel times are shown in Tables 2 and 3.

TABLE 1
Field Travel Time Versus FREQ Model Travel Time by Freeway and Direction

Freeway	Direction	Peak	Corridor		
			Field TT[1]	FREQ TT[1]	% Diff
US 101	NB	AM	27:00	24:53	-8%
		PM	34:41	32:56	-5%
	SB	AM	32:20	29:37	-8%
		PM	29:17	26:37	-9%
I-280	NB	AM	5:55	5:27	-8%
		PM	6:46	6:26	-5%
	SB	AM	6:59	6:30	-7%
		PM	5:23	5:31	3%

[1]Travel time in minutes:seconds

TABLE 2
US 101 Travel Time and Percent Change from Existing

Freeway	Direction	Peak	Scenario	Corridor TT[1]	% Diff
US 101	NB	AM	Existing	24:53	
			2010 NM[2]	28:13	13%
			2020 NM[2]	41:03	65%
		PM	Existing	32:56	
			2010 NM[2]	33:51	3%
			2020 NM[2]	48:53	48%
	SB	AM	Existing	29:37	
			2010 NM[2]	39:18	33%
			2020 NM[2]	39:05	32%
		PM	Existing	26:37	
			2010 NM[2]	34:43	30%
			2020 NM[2]	24:03	-10%

[1]Travel time in minutes:seconds
[2]No-metering scenario

TABLE 3
I-280 Travel Time and Percent Change from Existing

Freeway	Direction	Peak	Scenario	Corridor TT[1]	% Diff
I-280	NB	AM	Existing	5:27	
			2010 NM[2]	5:31	1%
			2020 NM[2]	6:09	13%
		PM	Existing	6:26	
			2010 NM[2]	7:11	11%
			2020 NM[2]	7:24	15%
	SB	AM	Existing	6:30	
			2010 NM[2]	10:43	65%
			2020 NM[2]	10:38	63%
		PM	Existing	5:31	
			2010 NM[2]	6:35	19%
			2020 NM[2]	10:21	88%

[1]Travel time in minutes:seconds
[2]No-metering scenario

Figures 4 to 7 at the end of this memo provide a complete set of FREQ contour maps that illustrate the relative congestion patterns for each scenario. Figures 8 to 11 provide detailed bottleneck analysis information. The PowerPoint presentation in Appendix B contains a complete set of FREQ contour maps that illustrate the relative congestion patterns for each scenario.

Conclusion

The results of the 2010 and 2020 no-metering analysis indicate that freeway operations degrade significantly compared with existing conditions (2003) for most scenarios, especially for US 101. The minor bottlenecks for the existing conditions analysis will become major bottlenecks in 2010 or 2020. (This may result in some bottlenecks being hidden due to upstream bottlenecks that limit traffic throughput.) The overall demand for traffic in the US 101 corridor is about “one lane” greater than capacity.

Appendix A –Existing Conditions Model Powerpoint

Peninsula Corridor Ramp Metering Study

Task 6:
Develop Baseline Freeway Analysis Models
(Existing Conditions Calibration)

Christine Warren

June, 2003

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Outline

- Volume Data and Adjustments
- FREQ Coding
- Calibration Results

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Volume Data

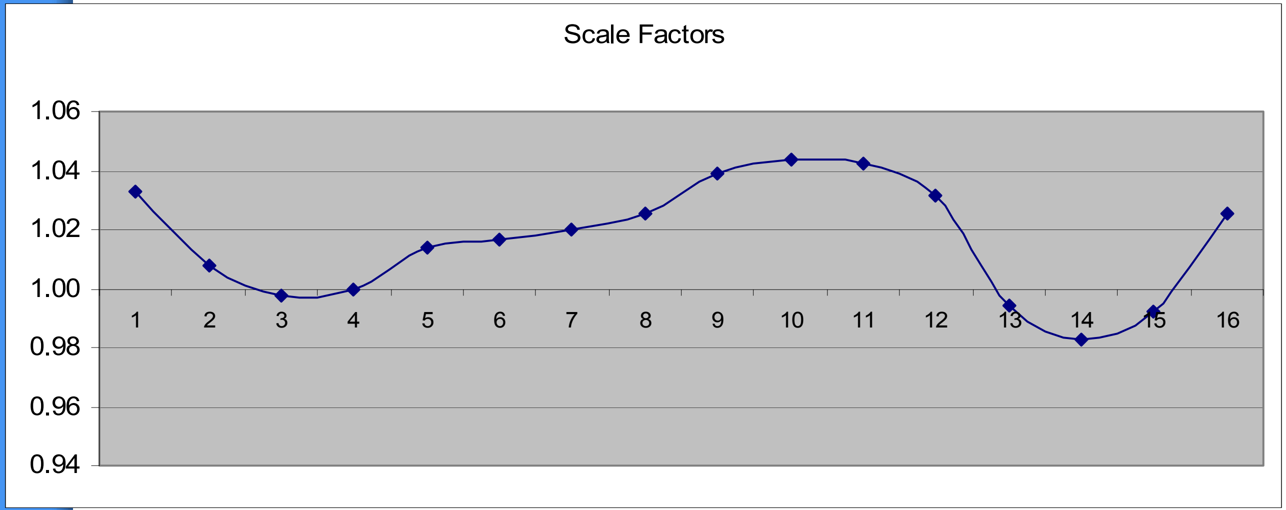
- **Caltrans Data**
  - 1999-2002
  - 101 majority in 2001; 280 majority in 2002
- **New Data Collection (Wiltec)**
  - 2003

Volume Adjustments

- **Volumes not adjusted for growth**
  - growth has been flat
- **Operations analyzed on non-HOV lanes**
  - assumed 13% HOV (from existing data)
- **Adjustments to get reasonable scale factors**
  - based on flips
  - based on previous project (1998)

Input Data

Southbound Tue-Thu PM	3-4 PM				4-5 PM				5-6 PM				6-7 PM			
Time of Day	:00-:15	:15-:30	:30-:45	:45-:00	:00-:15	:15-:30	:30-:45	:45-:00	:00-:15	:15-:30	:30-:45	:45-:00	:00-:15	:15-:30	:30-:45	:45-:00
Scale Factors	1.03	1.01	1.00	1.00	1.01	1.02	1.02	1.03	1.04	1.04	1.04	1.03	0.99	0.98	0.99	1.03
280 SB at County Line	669	706	748	794	865	913	938	941	939	943	929	898	872	841	791	721
SB on from John Daly	375	393	406	412	409	416	426	439	471	485	485	470	449	435	414	387
SB on from SB HWY 1	664	672	680	688	693	701	711	722	753	765	761	739	704	683	659	632
SB off to Sullivan	307	317	323	325	319	320	324	330	349	356	352	339	318	305	289	270
SB off to SB HWY 1	202	283	333	353	351	370	374	362	329	318	314	317	376	380	334	238
SB on from Sullivan	258	272	279	280	267	268	275	290	330	346	345	325	291	273	255	236
SB on from NB HWY 1	379	374	375	381	400	406	405	397	388	379	365	344	311	292	278	271
SB off to Serramonte	364	365	366	366	369	369	366	360	351	345	338	331	330	322	308	287
SB off to Hickey	188	198	207	215	221	229	236	242	256	263	262	254	242	234	222	208
SB on from Hickey	216	216	216	217	217	218	218	220	225	226	223	217	208	201	194	185
SB off to Westborough	203	211	220	231	244	255	265	273	279	287	299	313	343	358	359	348
SB on from Westborough	147	145	143	141	140	139	138	137	135	134	134	135	138	139	138	135
SB on from Avalon	108	110	112	114	117	119	120	119	118	118	117	117	119	119	117	113
SB off to Sneath	202	210	216	220	223	227	232	237	249	254	253	246	235	228	218	205
280 SB south of Sneath	1261	1281	1301	1318	1339	1357	1371	1380	1420	1430	1405	1346	1266	1208	1138	1057



FREQ Coding

- **Modeled AM and PM peak periods**
  - 4 hour peak period at 15-minute intervals
- **101 Northbound and Southbound**
  - San Francisco county line to Santa Clara county line
- **280 Northbound and Southbound**
  - San Francisco county line to I-380
- **Geometry based on**
  - field reconnaissance
  - location of ramp metering equipment

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FREQ Coding cont'd

- **Free flow speed of 70 mph**
- **Created capacity rules**
  - basic: 2100 vph; in CD area: 2000 vph
  - auxiliary lane: 1900 vph
  - CD lane: 1600 vph
  - HOV area:
    - *before heavy off-ramp or after heavy on-ramp: 1900 vph*
    - *before or after other ramp areas: 2000 vph*
- **Further capacity adjustments for calibration**

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Calibration Results - Travel Time

- **Overall corridor travel times within 10 percent**

			Overall		
Freeway	**Direction**	**Peak**	**Field TT**	**FREQ TT**	**% Diff**
101	NB	AM	0:27:00	0:24:53	-7.8%
		PM	0:34:41	0:32:56	-5.0%
101	SB	AM	0:32:20	0:29:37	-8.4%
		PM	0:29:17	0:26:37	-9.1%

			Overall		
Freeway	**Direction**	**Peak**	**Field TT**	**FREQ TT**	**% Diff**
280	NB	AM	0:05:55	0:05:27	-7.8%
		PM	0:06:46	0:06:26	-4.8%
280	SB	AM	0:06:59	0:06:30	-6.9%
		PM	0:05:23	0:05:31	2.5%

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Major Bottlenecks

- **101 Northbound**
  - AM: Hillsdale to SR92, Peninsula to Anza, Broadway to Millbrae
  - PM: University to Willow, Hillsdale to SR92, Broadway to Millbrae
- **101 Southbound**
  - AM: Poplar to 3rd, Whipple to Seaport, Willow to lane add, University to county line
  - PM: Seaport to lane add, Willow to lane add

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Major Bottlenecks cont'd

- **280 Northbound**
  - AM: None
  - PM: Sneath to West Borough, West Borough to Hickey
- **280 Southbound**
  - AM: Avalon to Sneath
  - PM: None

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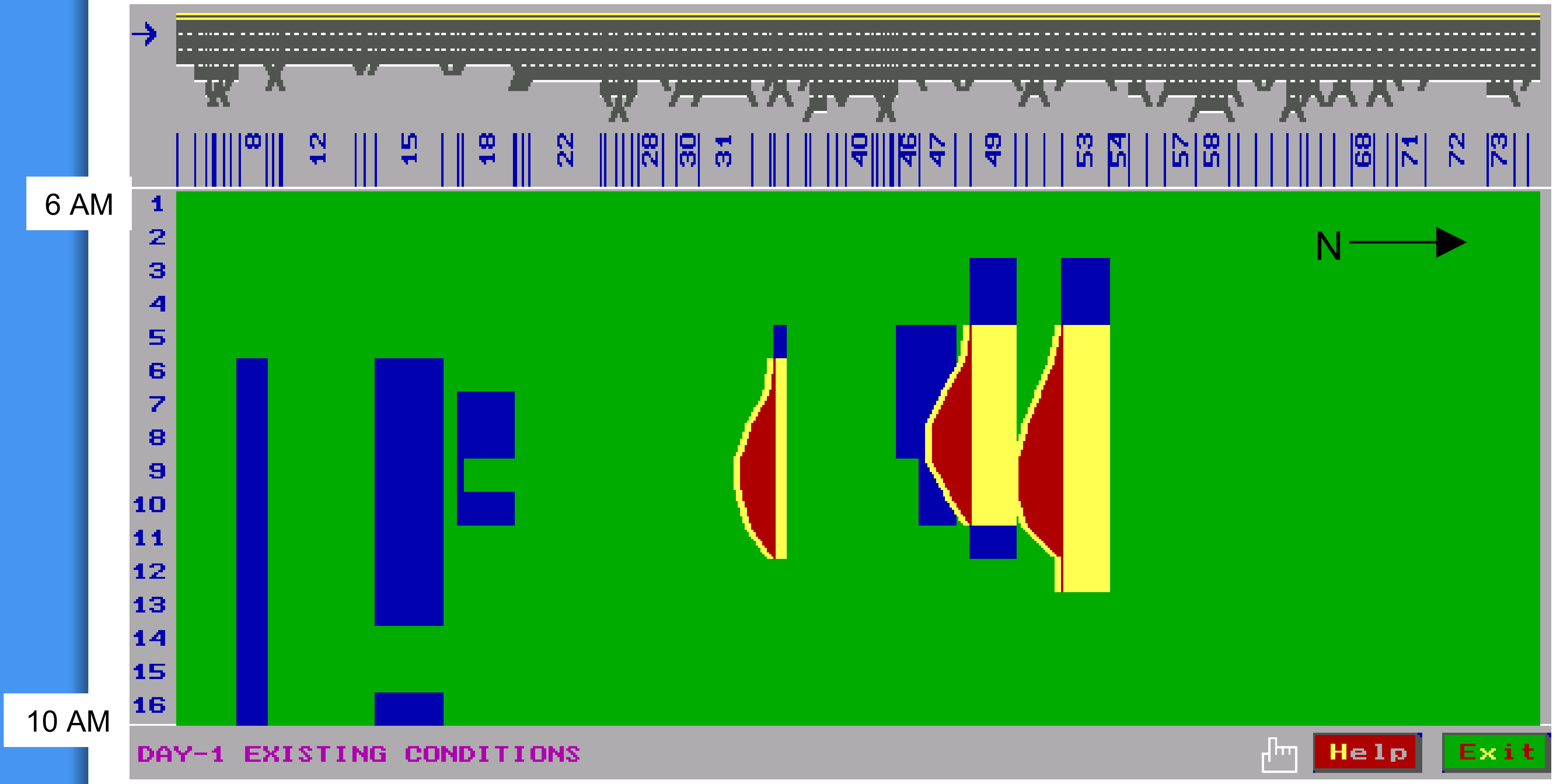
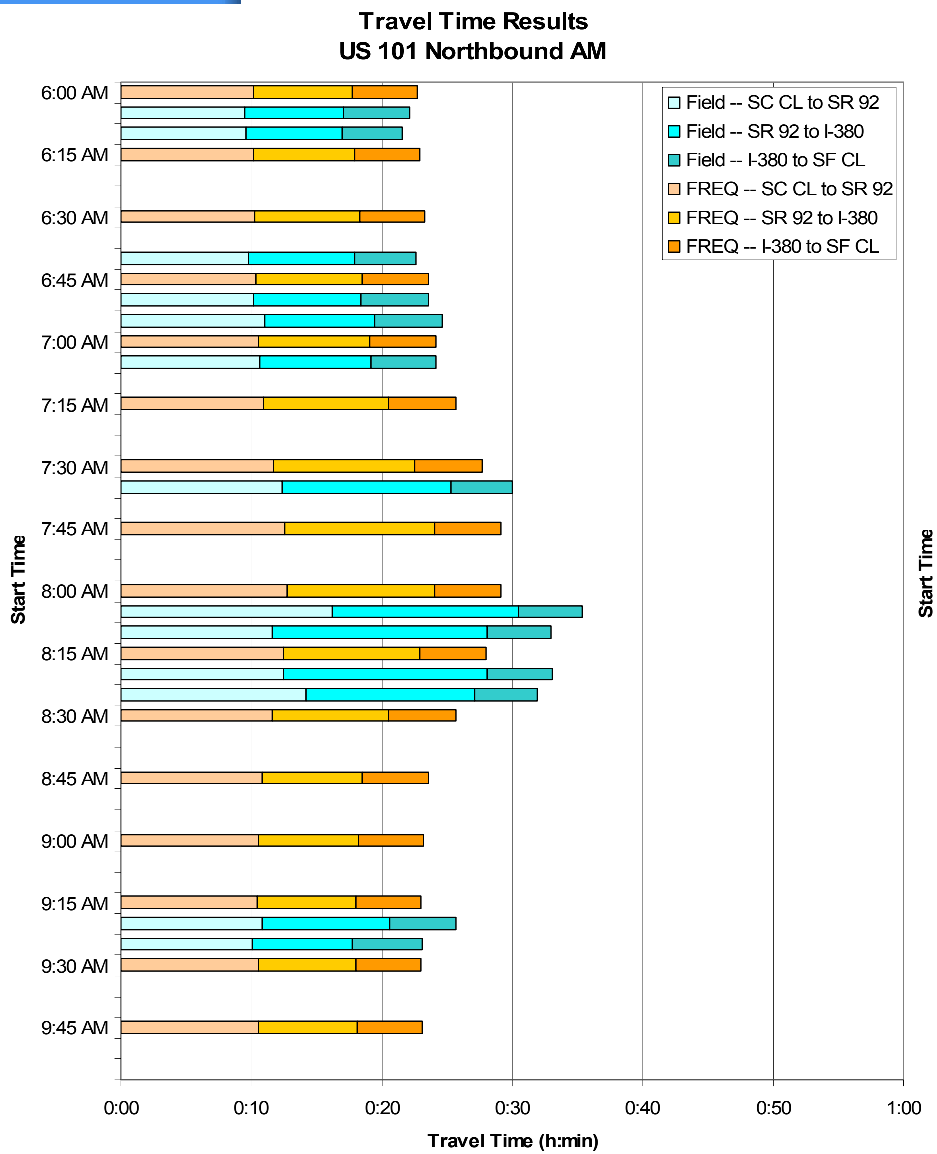
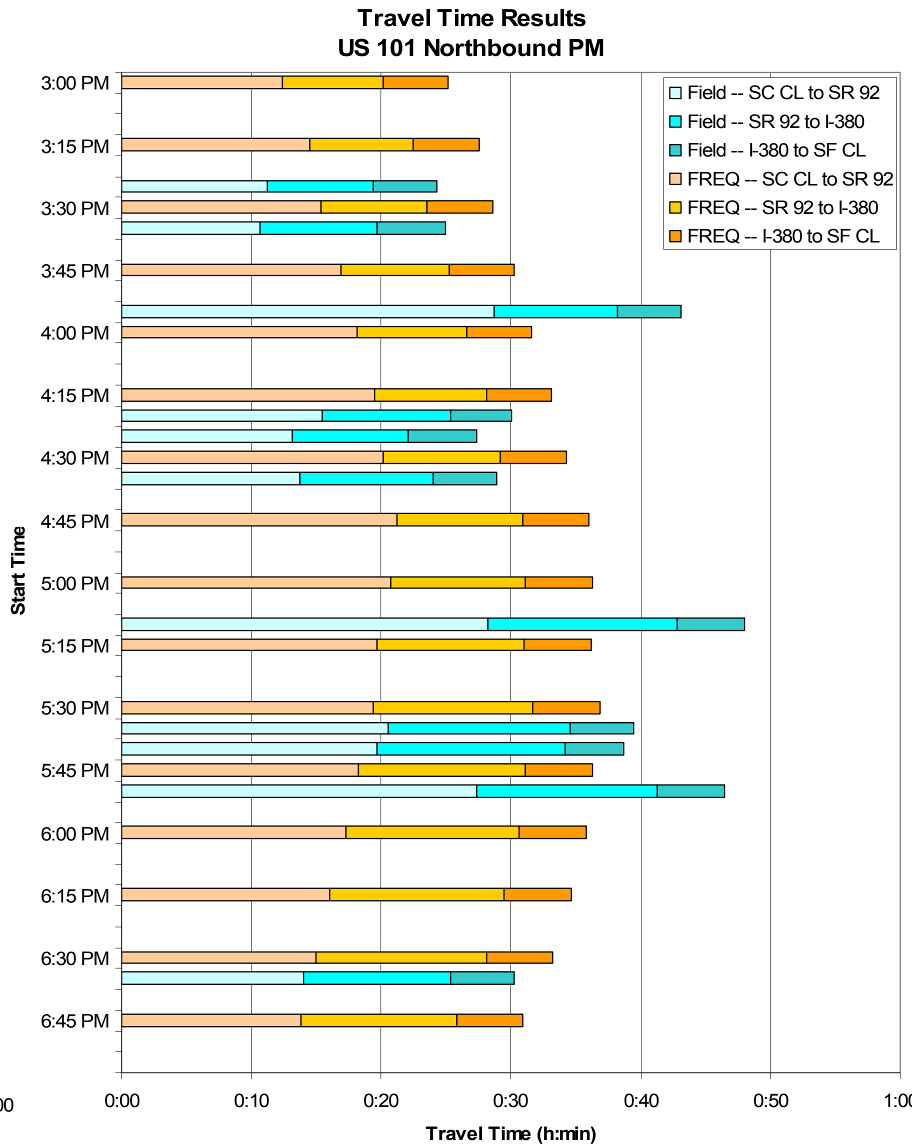
FREQ V/C Graphic

- **101 NB AM Peak**

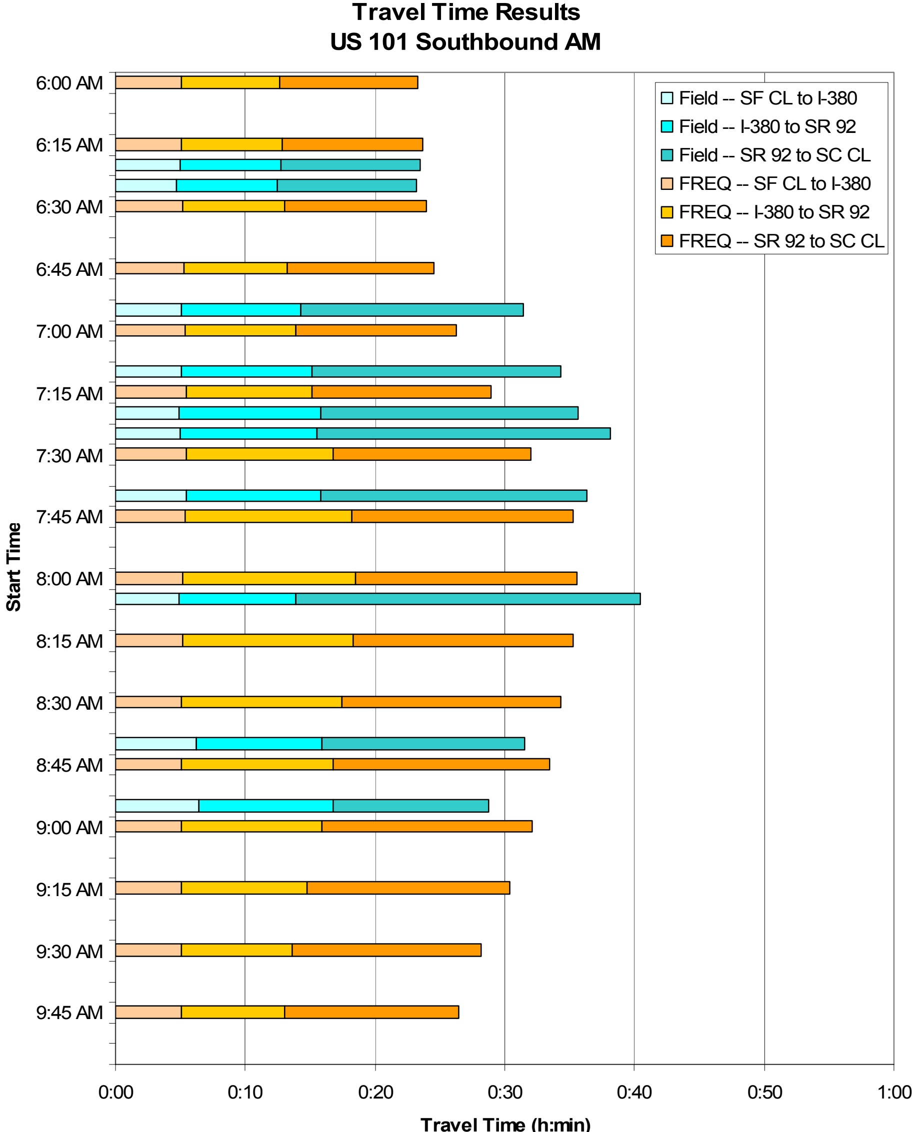


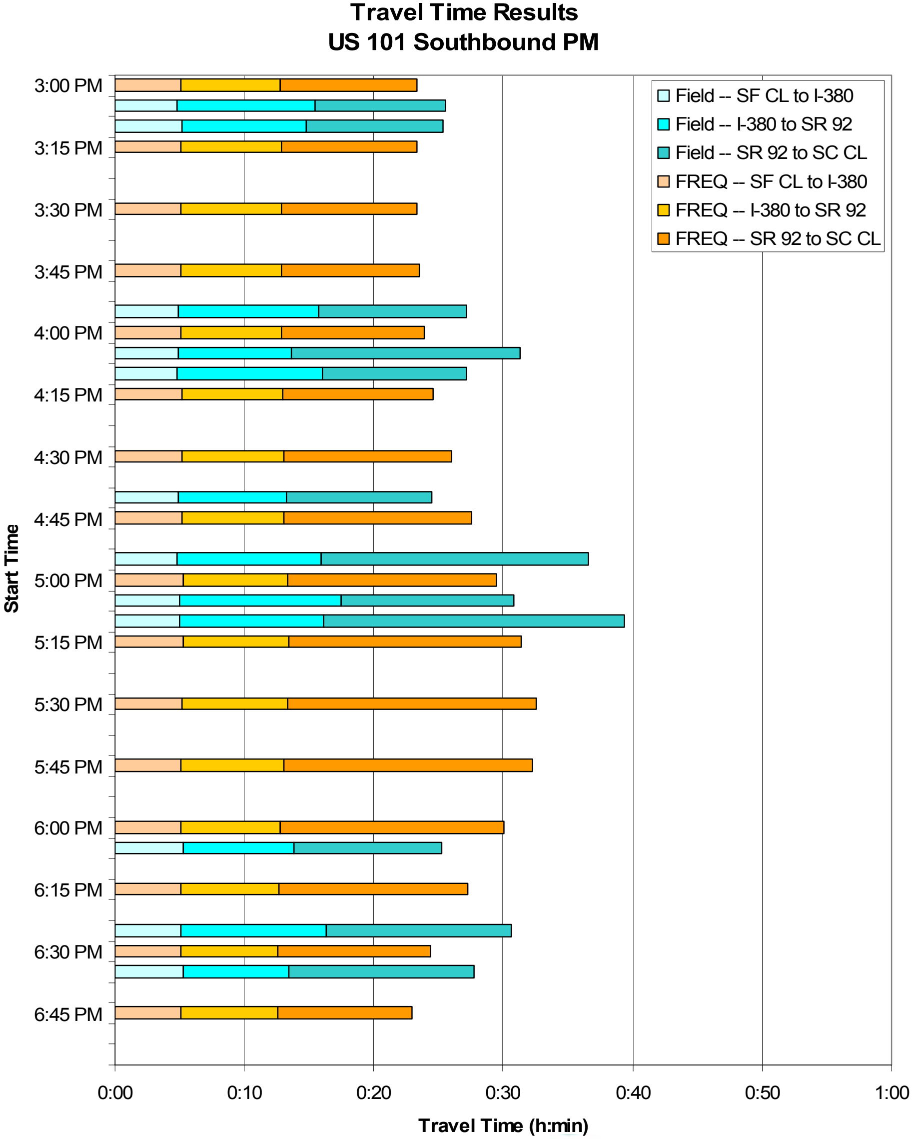
Travel Time Chart - 101 NB



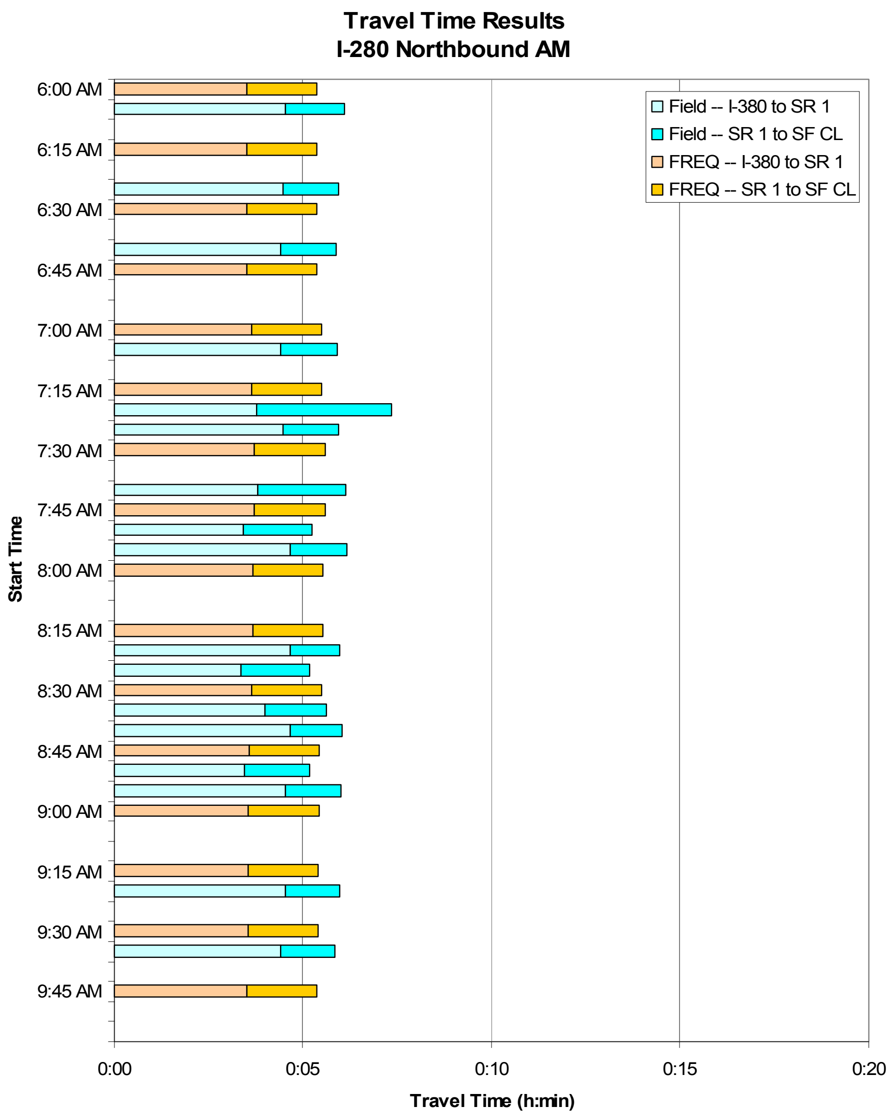


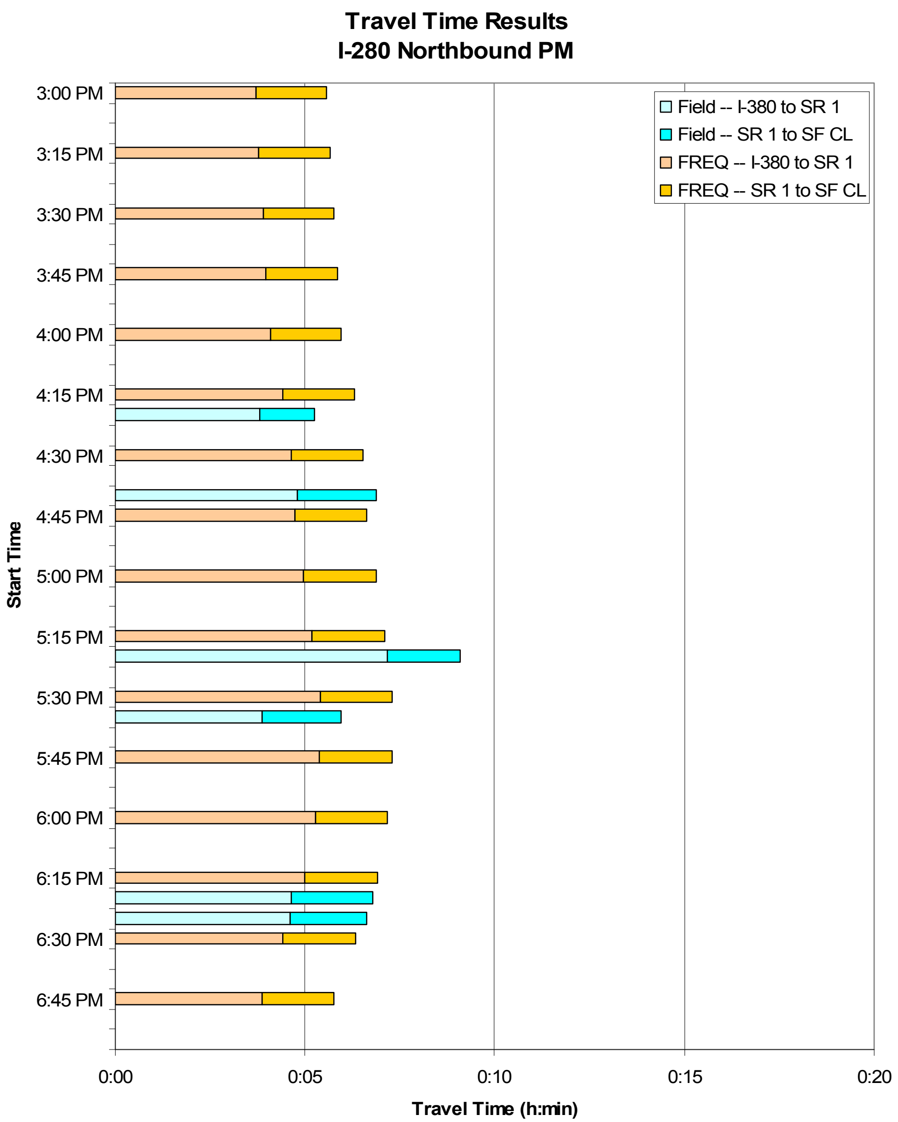
Travel Time Chart - 101 SB



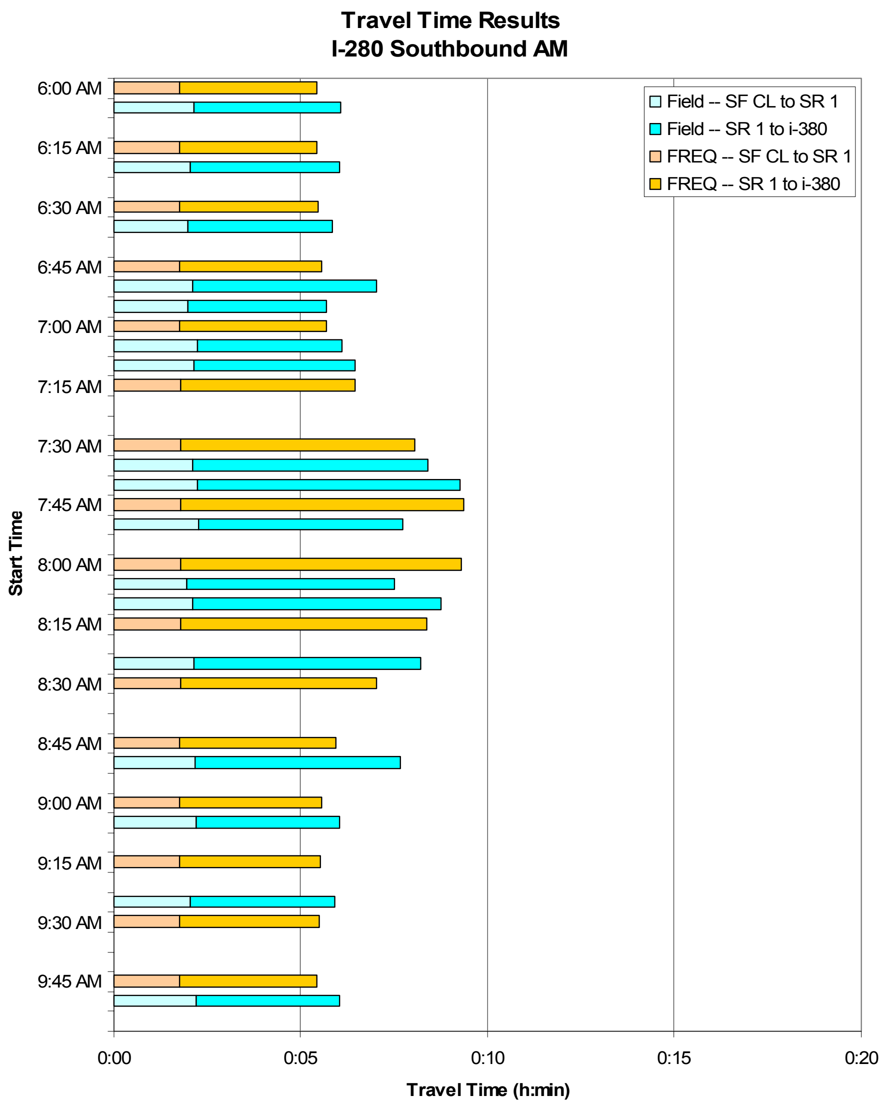


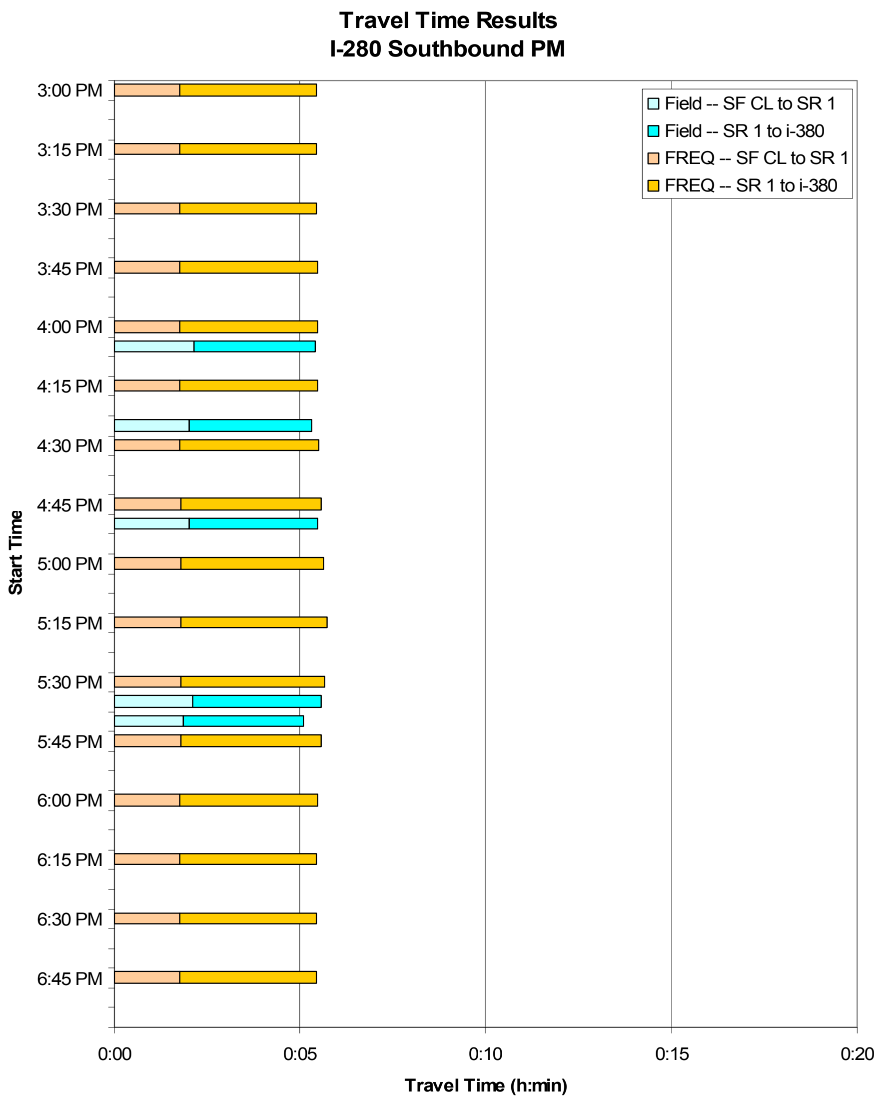
Travel Time Chart - 280 NB





Travel Time Chart - 280 SB





Next Steps

- **No-Build analyses 2010, 2020**
- **Build analyses for 2010, 2020**
  - capacity increase due to metering
  - determine ramp metering parameters

Appendix B –2010 and 2020 No-Metering Results Powerpoint

Peninsula Corridor Ramp Metering Study

Task 6:
Develop Baseline Freeway Analysis Models
(2010 and 2020 No-Metering Analysis)

August 6, 2003

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Outline

- **Coding Approach**
  - Geometry
  - Demand
- **Preliminary Results**
  - Operations/Congestion
  - Location of Bottlenecks
- **Discussion**

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No Metering 2010/2020 Coding

- **Copy Geometry from Existing**
- **Update to Reflect Improvements**
  - Oyster Point, Broadway, Ralston/Harbor, Holly, Marsh, Willow, and University
  - Capacity increases (aux lanes)
- **Increased Demand**

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Demands Were Increased Based on EMME/2 Results

2020 Percentage Growth Increases

	On-Ramps		Off-Ramps		Mainline	
	AM	PM	AM	PM	AM	PM
NB US 101	63%	27%	89%	31%	42%	21%
	6%	6%	43%	31%		
	59%	22%	56%	18%		
SB US 101	22%	50%	23%	56%	12%	14%
	26%	60%	13%	10%		
	40%	85%	40%	70%		
NB I-280	29%	0%	28%	10%	11%	6%
SB I-280	9%	26%	17%	41%	18%	8%

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Preliminary Results Indicate Significant Congestion

- Minor Bottlenecks Become Major Bottlenecks
- Demand is “One Lane” Greater Than Capacity
- Mainline Congestion at Entry Points
- Some Bottlenecks Hidden

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US 101 Travel Times Generally Increase Substantially

Freeway	Direction	Peak	Scenario	Corridor TT	% Diff from Existing
101	NB	AM	Existing	0:24:53	
			2010 NM	0:28:13	13%
			2020 NM	0:41:03	65%
		PM	Existing	0:32:56	
			2010 NM	0:33:51	3%
			2020 NM	0:48:53	48%
101	SB	AM	Existing	0:29:37	
			2010 NM	0:39:18	33%
			2020 NM	0:39:05	32%
		PM	Existing	0:26:37	
			2010 NM	0:34:43	30%
			2020 NM	0:24:03	-10%

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I-280 Travel Time Increases are Highest Southbound

Freeway	Direction	Peak	Scenario	Corridor TT	% Diff from Existing
280	NB	AM	Existing	0:05:27	
			2010 NM	0:05:31	1%
			2020 NM	0:06:09	13%
		PM	Existing	0:06:26	
			2010 NM	0:07:11	11%
			2020 NM	0:07:24	15%
280	SB	AM	Existing	0:06:30	
			2010 NM	0:10:43	65%
			2020 NM	0:10:38	63%
		PM	Existing	0:05:31	
			2010 NM	0:06:35	19%
			2020 NM	0:10:21	88%

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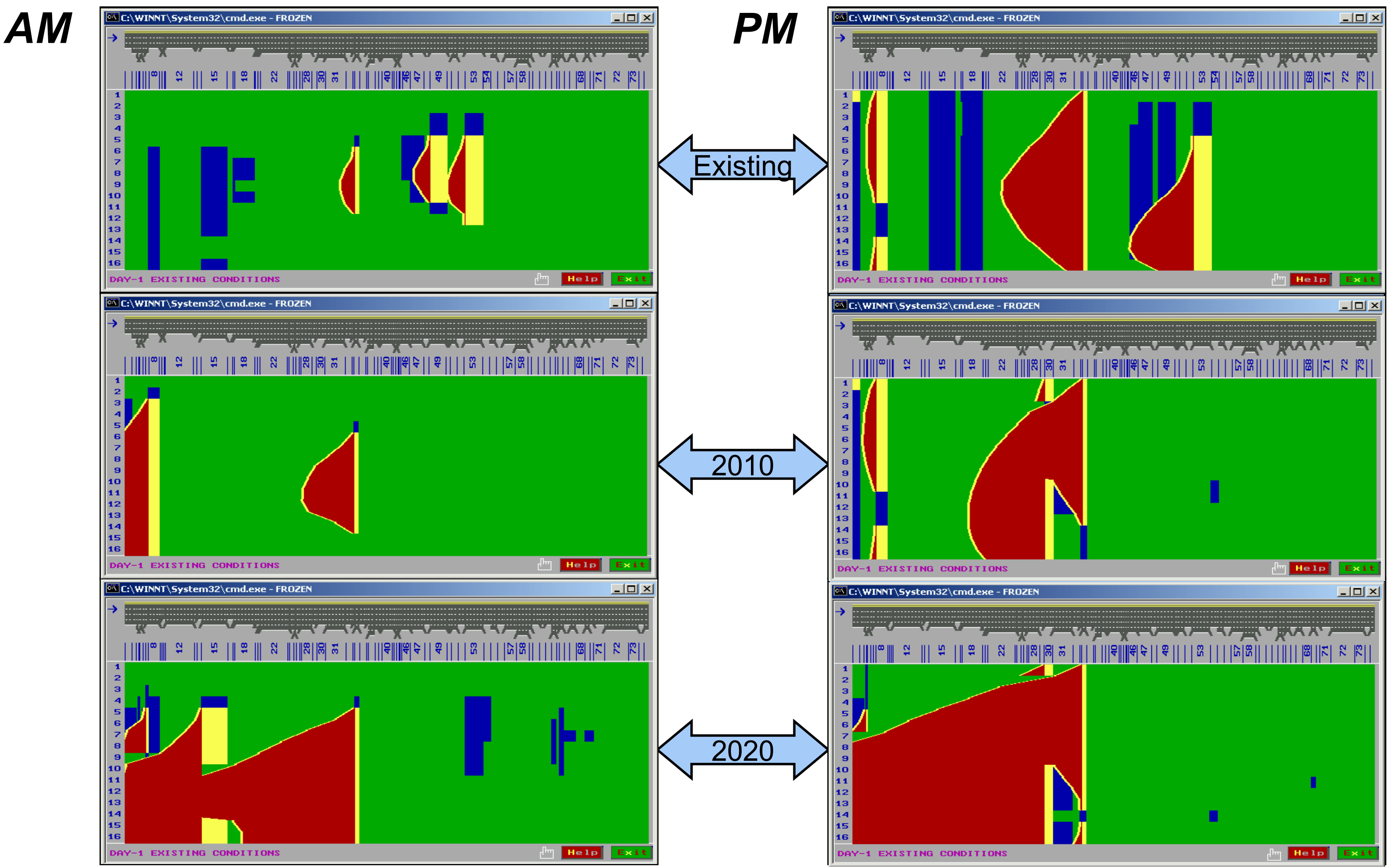
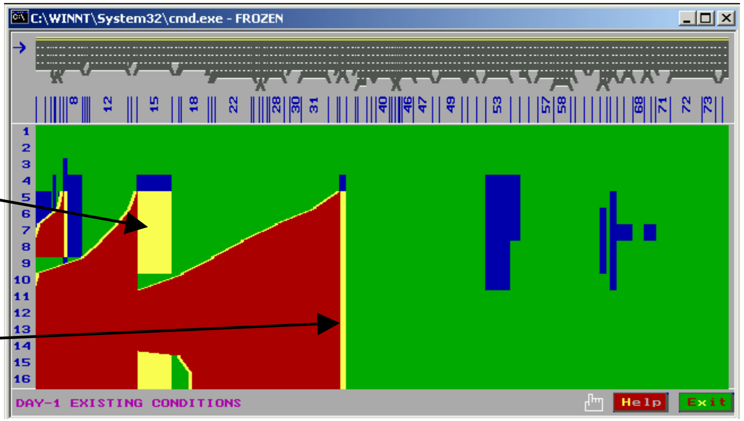
Queuing Diagrams - NB US 101



NB US 101 Detailed Results (2020 Analysis)

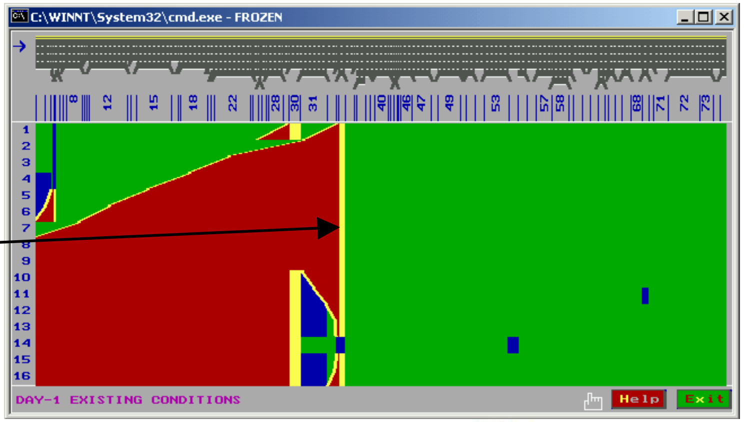
Bottleneck:
Marsh to Seaport
Exceeds Capacity:
960/hour at peak

Bottleneck:
SR 92
Exceeds Capacity:
2,320/hour at peak



AM

Bottleneck:
SR 92
Exceeds Capacity:
2,360/hour at peak



PM

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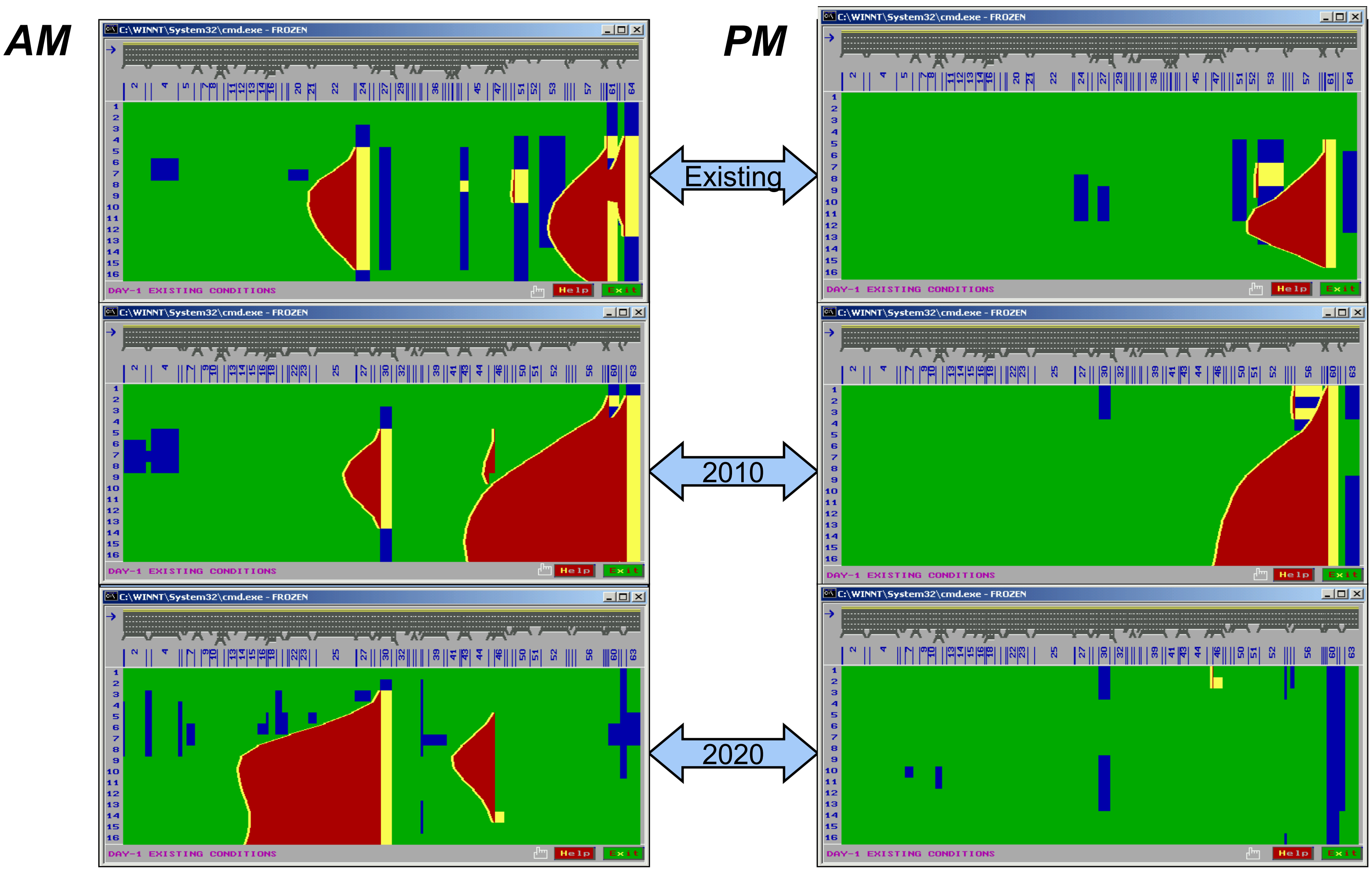
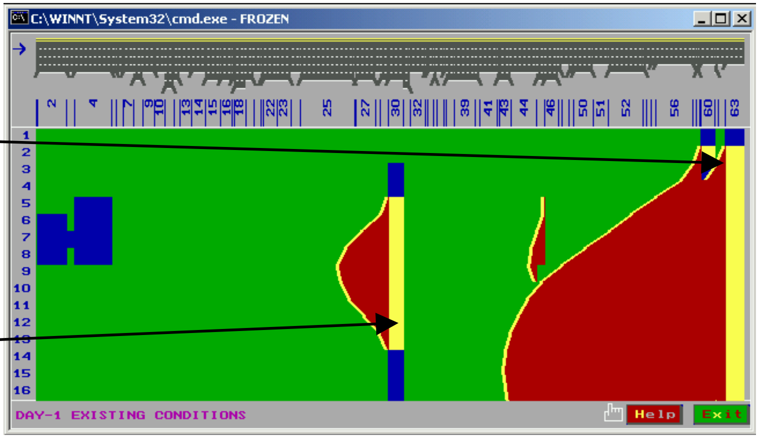
Queuing Diagrams – SB US 101



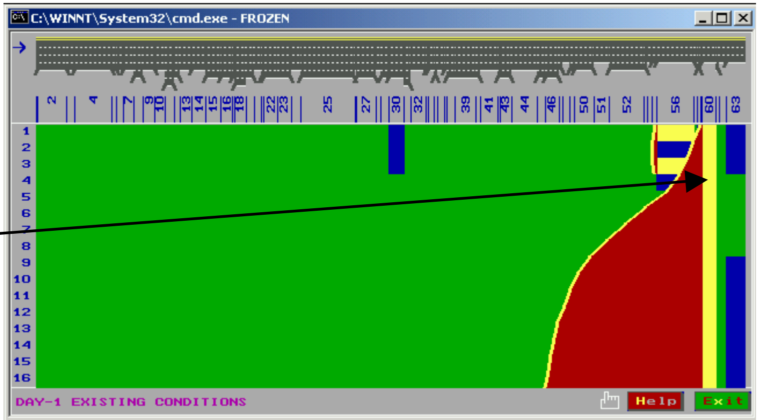
SB US 101 Detailed Results (2010 Analysis)

Bottleneck:
Mainline Exit
Exceeds Capacity:
1,060/hour at peak

Bottleneck:
SR 92
Exceeds Capacity:
730/hour at peak



AM



PM

Bottleneck:
Willow to University
Exceeds Capacity:
1,140/hour at peak

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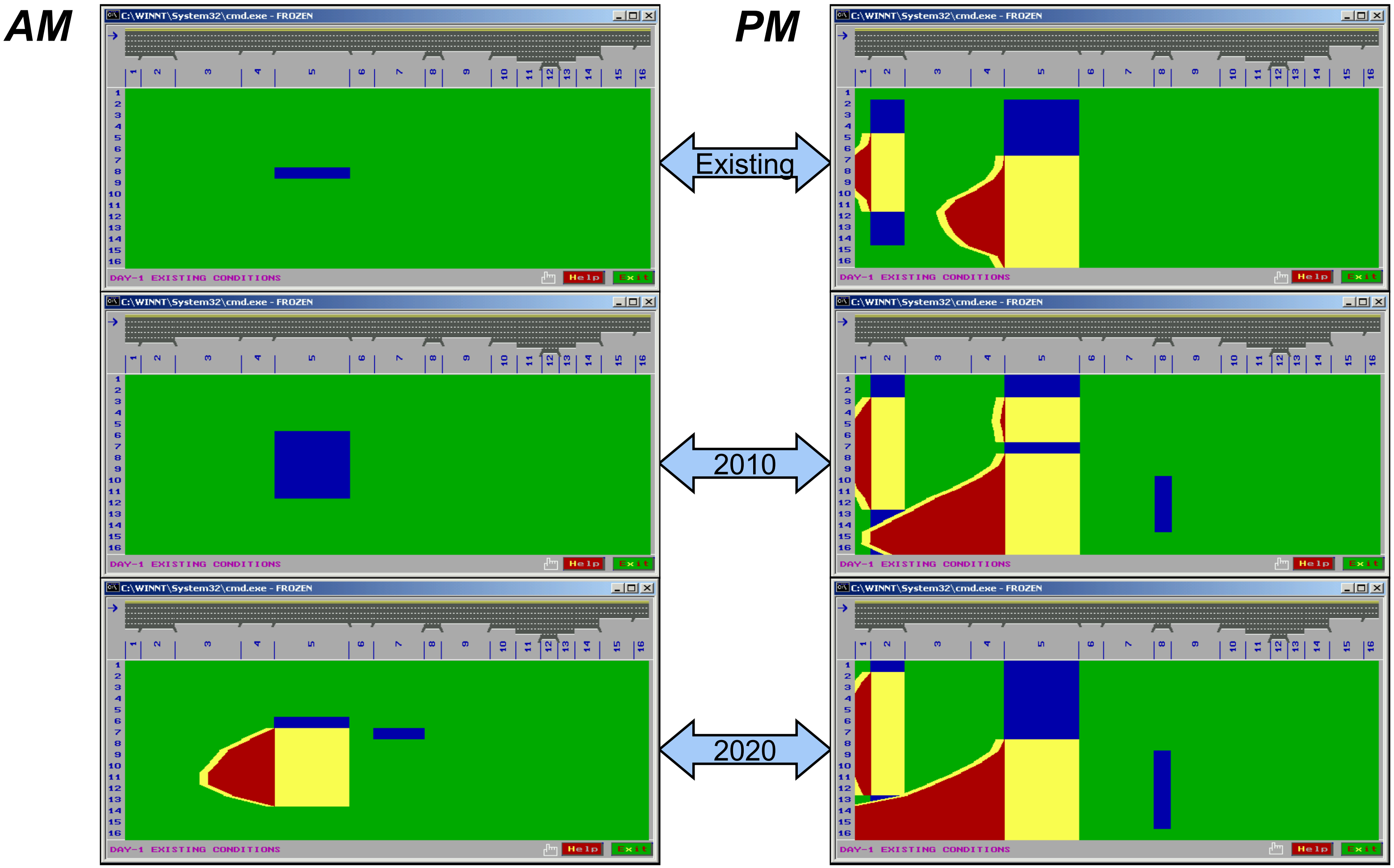
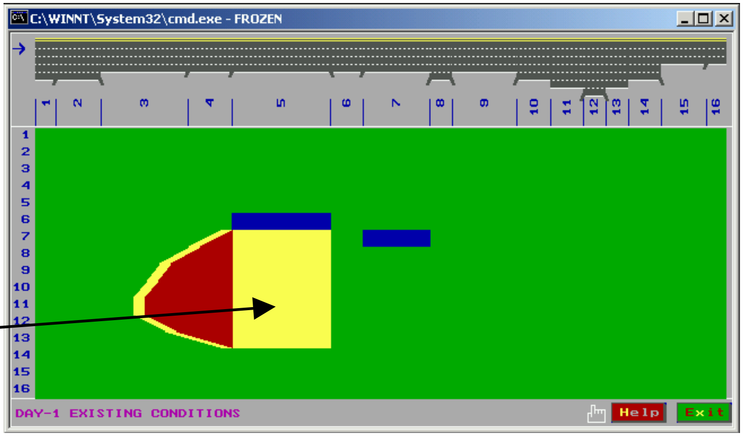
Queuing Diagrams - NB I-280



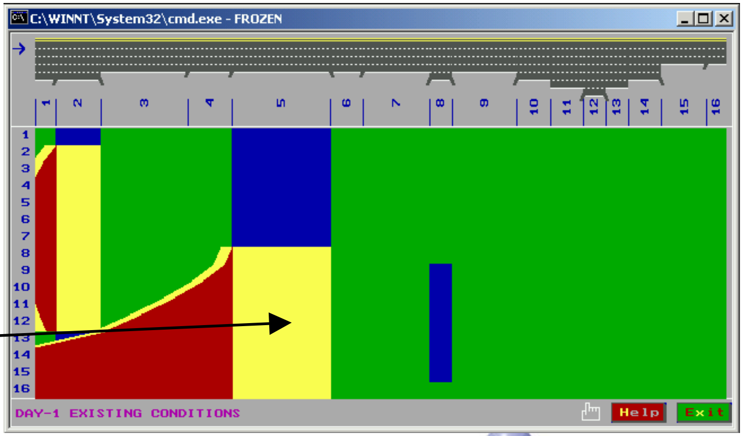
NB I-280 Detailed Results (2020 Analysis)

Bottleneck:
Westborough to Hickey
Exceeds Capacity:
290/hour at peak



AM

Bottleneck:
Westborough to Hickey
Exceeds Capacity:
420/hour at peak



PM

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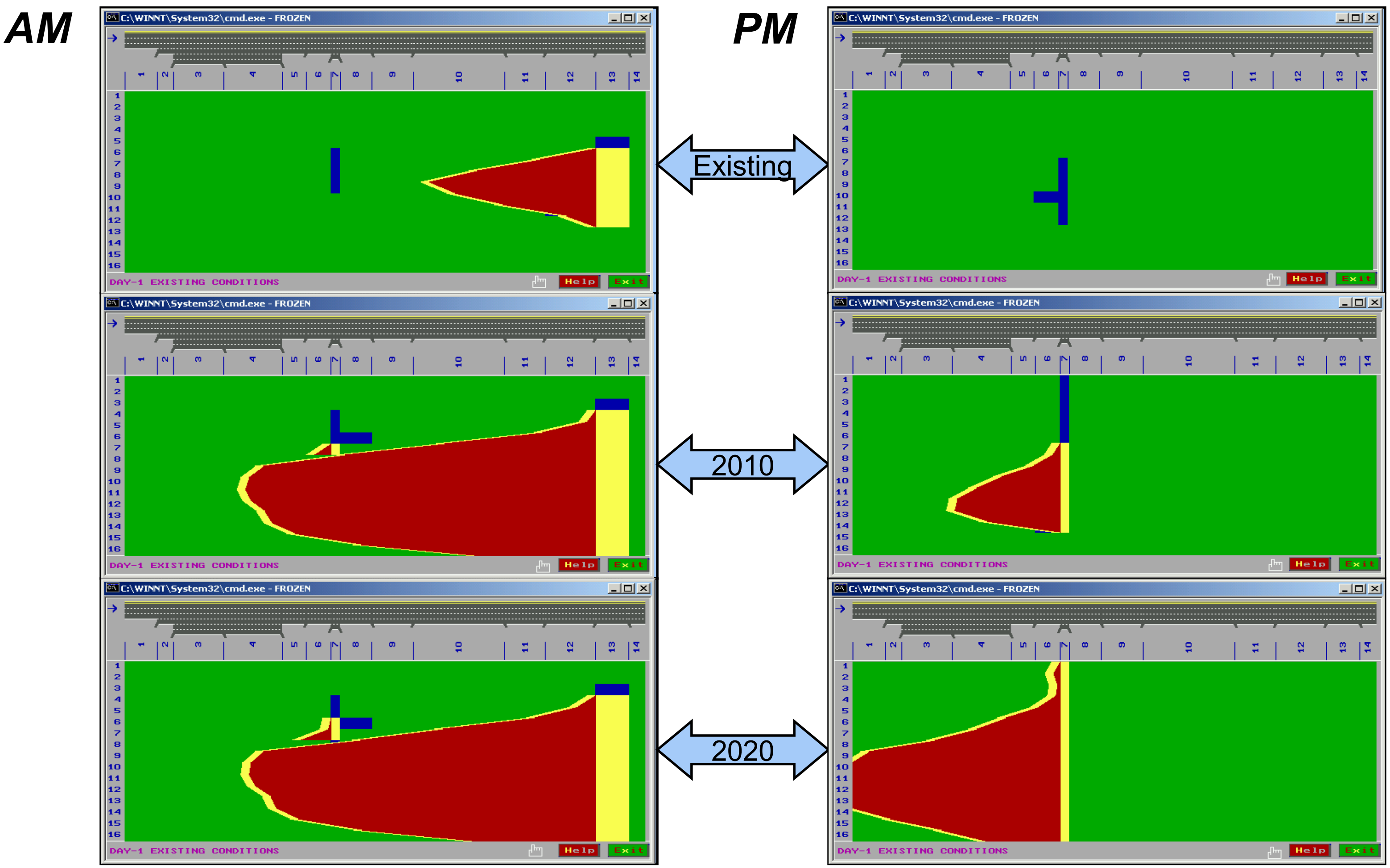
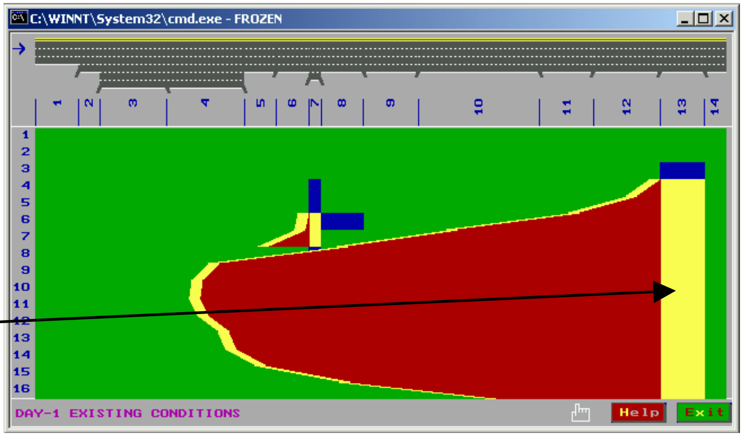
Queuing Diagrams - SB I-280



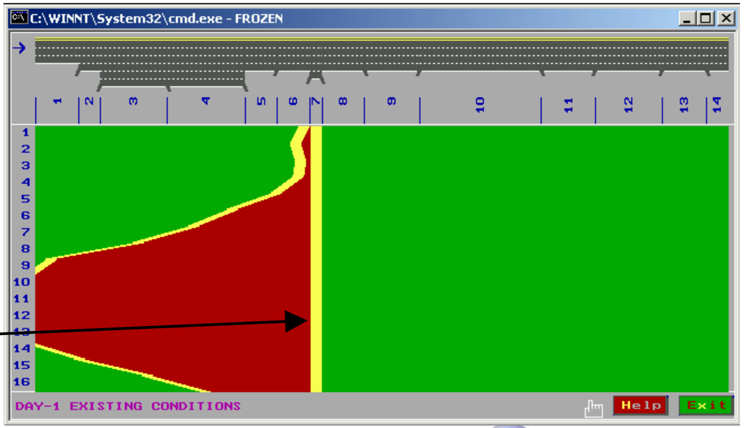
SB I-280 Detailed Results (2020 Analysis)

AM



Bottleneck:
Avalon to Sneath
Exceeds Capacity:
1,190/hour at peak

PM



Bottleneck:
Highway 1
Exceeds Capacity:
1,650/hour at peak

Discussion Items

- **Do the Demand Growth Rates Make Sense?**
- **Are the Future Operations Believable?**
- **What Are Our Options?**
  - Do Nothing
  - Spread/Reduce Demand
  - Increase Capacity

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Appendix F – Ramp Metering Parameters and Scenarios

DKS *Associates*
TRANSPORTATION SOLUTIONS

MEMORANDUM

TO:	Peninsula Ramp Metering Study – Working Group
FROM:	Terry Klim
DATE:	July 11, 2003
SUBJECT:	Revised Technical Memorandum #5 – Ramp Metering Parameters and Scenarios

P/A No. 03018-000x007

INTRODUCTION

This technical memorandum is one deliverable for Task 7 ("Conduct Freeway Operational Analysis") of the Peninsula Corridor Ramp Metering Study. The objective of this study is to identify the potential impacts of ramp metering within the Peninsula Corridor. The study area includes US Highway 101 (US 101) within San Mateo County, and the northern section of and Interstate 280 (I-280), from I-380 to the San Francisco County line.

The first part of the project focuses on the freeway operational impacts of ramp metering. The goal of this series of steps is to determine if ramp metering can provide any significant operational benefits to the freeways in the study area. Specific issues to be addressed as part of the freeway operational analysis include:

- To what extent can ramp metering improve freeway operations?
- How will ramp metering and specifically queues from ramp meters, impact arterial operations?
- What are recommended meter operating parameters?

This part of the study is being accomplished by developing traffic simulation models of the freeway systems for two horizon years (2010 and 2020), adding ramp metering to the systems, and comparing the predicted performance with and without ramp metering. If it is determined that ramp metering may benefit some or all freeways, the second part of the project will focus on the potential impacts to the arterial street system throughout the study network.

A necessary input to the freeway operational analysis task is the definition of the metering scenarios that will be tested. This memorandum describes a set of the parameters that may be used to differentiate between scenarios, and identifies the set of scenarios to be examined as part of this study.

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RAMP METERING DESIGN PARAMETERS

There are a myriad of options for ramp metering, so the first step is to make decisions about the parameters that define a ramp metering system. This may be a challenging task, however, given the complexity and number of possible permutations for a ramp metering system. Eight different ramp metering parameters are introduced and discussed below. These parameters are: geographic limits, types of metering, metering rates, ramp geometrics, queue limits, ramp delay, freeway performance, and HOV treatment. A summary table is provided at the end of the section that outlines a list of key questions for ramp metering design.

Geographic Limits. The first parameter to consider in developing ramp metering alternatives is the extent of ramp metering coverage. This may be pre-defined by geographic or jurisdictional boundaries, but in many cases there are opportunities to change limits. At a minimum, ramp metering should include all current and anticipated congested freeway segments. It may be difficult to develop an effective ramp metering plan if only a few ramps can be metered; the volumes at metered on-ramps should constituent a large percentage of traffic on the freeway. It is generally necessary to extend ramp metering limits beyond congested areas so that drivers in one area or jurisdiction are not forced to endure long queues compared to other areas.

Types of Metering. On-ramp metering is typically used for most installations. Freeway to freeway connector metering is less common, but can be particularly useful because connectors tend to have high traffic volumes. A critical issue for connector metering is to determine if queues from meters might affect freeway operations on the feeder freeway. Mainline metering is relatively rare, but can be appropriate in certain circumstances (e.g. Bay Bridge).

Metering Rates. There is a practical minimum and maximum metering rate that can be used on each ramp. This becomes a key issue for low- and high-volume ramps. For low volume ramps, it may not be possible to meter traffic so that the on-ramp throughput is reduced during the metering period. The issue is even more critical for high-volume ramps, which obviously contribute more to freeway congestion. For these ramps, it may be difficult to set a metering rate that is high enough so that extensive queues do not form. If this is the case, metering may not be used on a particular high-volume ramp, causing two problems. First, other, lower-volume ramps may need to be metering more heavily to make up the difference. Then, vehicles may divert and use the unmetered ramp(s), exacerbating the problem. One solution to this problem is to add lanes to high-volume ramps, which increases the range of usable metering rates and also provides more storage.

For single lane ramp metering, the maximum rate typically used is 900 vehicles per hour (vph), using a 2.5 second red phase and a 1.5 second green phase. The minimum rate used is 240 vph, based on a 13.5 second red phase and a 1.5 second green phase. (It has been found that drivers start ignoring the red ramp meter signal once the total cycle length exceeds 15 seconds.) Caltrans uses minimum and maximum rates of 240 and 900 vph.

Platoon metering can be used to increase the maximum rate. With this system, two or more cars per lane are released every green cycle. Two car platoon metering (using a 2.5

second red phase and a 3 second green phase) can theoretically yield about 1300 vph., but 1050 vph is a more practical limit. Platoon metering is not commonly used in California (there are a few locations in the South Bay), but has been employed in Texas.

Ramp Geometrics. With multiple-lane ramps, the maximum ramp metering rate can be extended. With a two-lane on-ramp, vehicles can be released from alternate lanes every two seconds (i.e., using a four second cycle for each lane), providing a theoretical maximum rate of 1800 vph (in practice, rates higher than 1600 vph are rarely achieved). Obviously, this is only feasible on ramps with more than one lane, but a key consideration in ramp metering design is to identify ramps that can be widened. An assessment of individual on-ramps in the study area and the potential feasibility for improvement is provided in Technical Memorandum #2 for this study.

HOV Treatment. HOV priority lanes (where HOVs and transit vehicles use designated lanes and receive priority entry onto the freeway) can be an effective way to reduce person travel times. Since HOVs are avoiding most ramp delays and benefiting from reduced freeway travel times, more people have shorter trip times. This has the added benefit of encouraging mode shifts away from SOVs. However, SOVs will then be forced to wait longer at ramp meters, and may illegally use the HOV priority lanes. This can increase frustration for honest drivers and reduce the effectiveness of the ramp metering system. Therefore, enforcement is a critical element of an HOV priority implementation. Caltrans design guidelines mandate enforcement areas at new ramp metering installations. An assessment of individual on-ramps in the study area and the potential feasibility for improvement is provided in Technical Memorandum #2 for this study.

Queue Limits. Many ramp metering systems use spillback detectors to prevent queues from reaching arterials and effectively limit queues to the length of the on-ramp. One common problem that is reported for new ramp metering installations is that ramp queue lengths are too short, and override (queue) detectors contradict the intent and limit the effectiveness of ramp metering.

In specifying queue limit parameters for ramp metering design, some options are available for adding to queue limits. First, ramp geometries can be examined to see where queues could extend back to surface streets without affecting arterial signal operations. Signal timing and phasing can be adjusted to allow queues to form in turn lanes that do not affect other arterial traffic.

Adding lanes to on-ramps to provide more storage may also be a cost-effective way of improving freeway operations. Placement of the ramp meter stop bar also affects storage, although there should be at least 300 to 600 feet of acceleration distance between the stop bar and merge area on the freeway. The distance between the ramp meter stop bar and the merge point depends on the grade of the ramp and the traffic composition (especially trucks).

Ramp Delay. Related to queue limits is the maximum acceptable delay for vehicles queued at a ramp meter. This is especially important for ramps with significant storage and/or low metering rates. For example, 500 feet of storage might accommodate 20 vehicles. With a metering rate of 300 vph, the delay for vehicles on this ramp could reach four minutes. This might cause vehicles to divert to alternate routes. Also, even though a wait of a few minutes might be compensated by reduced freeway travel time, drivers are more likely to notice the ramp delay than the improved freeway speeds.

Freeway Performance. Ramp metering programs are intended to improve freeway performance, so specific freeway performance goals could be specified as part of ramp metering design. A simple goal is to eliminate all freeway performance breakdowns (i.e., congestion), but that may not be possible on some congested freeways. If ramp delays are too great, long queues, heavy diversion, ramp meter violations, and negative public reaction may result. Therefore, a more attainable goal may be to reduce congestion as much as possible within the constraints of specific ramp queue limits. In the field, this may be best implemented using a dynamic control algorithm that can recognize the extent of mainline freeway queuing.

Obviously many of these parameters are interrelated. For example, the potential metering rates and possibility of HOV priority lanes at a particular ramp are, in part, a function of that ramp's geometrics and potential for modification. Similarly, queue limits and metering rates determine maximum delay.

To summarize, key questions related to each of the design parameters described above are listed in Table 1. Responding to these questions is a good way to formulate a set of ramp metering alternatives.

Table 1
Issues for Formulating Ramp Metering Alternatives

Issue	Question
GEOGRAPHIC LIMITS	What are the geographic limits for the ramp metering area, and which specific ramps should or can be metered?
TYPES OF METERING	Is freeway connector or mainline metering a possibility? Where can this approach be used?
METERING RATES	What range of metering rates can be used?
RAMP GEOMETRICS	Can on-ramps be reconstructed to better accommodate ramp metering?
HOV TREATMENT	Where can or should HOVs and transit vehicles be provided with priority entry to the freeway?
QUEUE LIMITS	Where can on-ramp queues extend back to surface streets? How far can queues extend?
RAMP DELAY	What magnitude of delay is acceptable at ramp meters?
FREEWAY PERFORMANCE	What are the desired or acceptable mainline speeds and/or congestion levels after metering is implemented?
Source: DKS Associates, 2003	

METERING SCENARIOS FOR TESTING

For the purposes of the Freeway Operational Analysis, it is proposed that three (3) scenarios be examined for each forecast year:

- No Metering
- Scenario 1 – Constrained Ramp Queues/Conservative Metering
- Scenario 2 – Mainline Delay Reduction/Aggressive Metering

A brief description of each scenario is provided below. The design parameters for the two proposed metering scenarios are also summarized in Table 2. While in many respects there is no difference in the two metering scenarios, overall they represent opposite ends of the ramp metering spectrum. If ramp metering is implemented within the study area, it is most likely that the recommended operating parameters would fall somewhere in between these two scenarios.

No Metering

For both 2010 and 2020, an initial FREQ model run without ramp metering will be performed. The results from these runs will serve as the baseline for evaluation of ramp metering. These base models include the programmed/planned network improvements described in Technical Memorandum #3.

Scenario 1

This scenario essentially reflects a "conservative" metering alternative with respect to both operations and capital improvements. It is intended to illustrate what benefit ramp metering may produce on the freeway if the impact to local streets is minimized.

In this scenario, queues from the ramp meters would generally be limited to the length of the on-ramps with no spillback onto local streets. At select ramp locations, the queue limit may be extended where it appears that queues could extend back to surface streets without affecting arterial signal operations. Of course, depending on traffic volumes, metering rates and ramp geometrics, the queues at some ramps may not even reach this limit.

In addition to the programmed/planned network improvements described in Technical Memorandum #3, this scenario will include improvements to individual on-ramps of the nature described in Technical Memorandum #2 - On-Ramp Geometric Assessment. Potential improvements include widening for the addition of an HOV priority lane, an additional mixed flow metered lane, and/or additional ramp storage. Any one or combination might be recommended at a particular on-ramp. Where widening for throughput was considered, the volume at the ramp was used to determine if an HOV priority lane would be added or a mixed-flow lane would be added. For higher volume ramps, where an additional metered lane would likely be needed, the latter was selected. However, for Scenario 1, capital improvements are limited to those locations that are relatively easy (receive a "high" feasibility rating). Note that improvements were not recommended in some locations with a "high" rating, because they would not be expected to be beneficial for ramp metering.

Scenario 2

This scenario reflects a more "aggressive" approach in terms of both meter operation and capital improvements. This scenario seeks to illustrate what the impacts may be if the primary objective was to maximize the benefit to the freeway mainline.

The guiding principle for this scenario is achieving a specific reduction in freeway mainline delay. Given the level of existing and forecast congestion along the study corridor, it is unreasonable to expect that all congestion could be eliminated or that a particular average speed could be attained with ramp metering. Thus, for this scenario the goal was set as a relative reduction in mainline delay versus the no metering scenario. As a starting point, a 50% delay reduction target has been set. However, this target could be changed based on results from initial FREQ runs. Furthermore, it may be appropriate to vary the delay reduction goal may vary by time period, by direction, and by facility (US 101 versus I-280).

Under this scenario, queues at individual ramps would be allowed to extend beyond the limit of the ramps. As deemed appropriate, extended limits (e.g. beyond the ramp itself) on queue lengths and maximum delays will be specified at some locations if the unconstrained situation produces highly unreasonable queues. This scenario also assumes a more aggressive ramp improvement program. Specifically, Scenario 2 includes ramp improvements where feasible ("H" and "M" ratings) and appropriate. As with Scenario 1, the specific ramp improvements to be assume din this scenario will be determined following the initial FREQ runs.

Table 2
Proposed Ramp Metering Scenarios for Testing

Design Parameter	Scenario 1 – Ramp Queue Limits	Scenario 2 – Minimize Mainline Delay
GEOGRAPHIC LIMITS	All on-ramps in study area: US 101 – SF to SC I-280 – SF to I-380	Same as Scenario 1
TYPES OF METERING	All on-ramps and low-volume freeway connectors (exact connectors to be determined); no mainline metering	Same as Scenario 1
METERING RATES	Per Caltrans standards; vary by ramp	Same as Scenario 1
RAMP GEOMETRICS	Improve ramps where critical and relatively easy ("high" feasibility for improvement)	Improve ramps where appropriate and feasible ("high" or "medium" feasibility for improvement)
HOV TREATMENT	Improve ramps where critical and relatively easy ("high" feasibility for improvement)	Improve ramps where appropriate and feasible ("high" or "medium" feasibility for improvement)
QUEUE LIMITS	Limit to length of on-ramp	No limit[1]
RAMP DELAY	No specific constraint, but a function of queue limit	Same as Scenario 1
FREEWAY PERFORMANCE	No objective	50% reduction in mainline delay[2]

Notes:

1. *As deemed appropriate, extended limits (e.g. beyond the ramp itself) on queue lengths and maximum delays will be specified at some locations if the unconstrained situation produces highly unreasonable queues.*
2. *Percent reduction may change following initial runs and may vary by corridor, time period, and/or direction.*

Source: DKS Associates, 2003

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Appendix G – Future Year Ramp Metering Freeway Analysis Results

Peninsula Corridor Ramp Metering Study: Ramp Metering Analysis Results (Without Arterial Diversion Analysis) - Final

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DATE: February 27, 2004

Introduction

This technical memorandum is the second deliverable for Task 7 ("Conduct Freeway Operations Analysis (Proposed Metering Scenarios)") for the Peninsula Corridor Ramp Metering Study. The objective of the Peninsula Corridor Ramp Metering Study is to assess the role of ramp metering for helping manage traffic within the Peninsula Corridor. The study area includes US Highway 101 (US 101) within San Mateo County, and the northern section of and Interstate 280 (I-280), from I-380 to the San Francisco County line.

The first part of the project focuses on the freeway operational impacts of ramp metering. The goal of this series of steps is to determine if ramp metering can provide any significant operational benefits to the freeways in the study area. This is being accomplished by developing traffic simulation models of the freeway systems for two horizon years (2010 and 2020), adding ramp metering to the systems, and comparing the predicted performance with and without ramp metering. If it is determined that ramp metering may benefit some or all freeways, the second part of the project will focus on the potential impacts to the arterial street system throughout the study network.

The results for the existing conditions (2003), 2010 and 2020 no-metering FREQ models were documented in Technical Memorandum No. 4 ("Peninsula Corridor Ramp Meeting Study: Baseline (No-Metering) Freeway Analysis Results"). This memorandum focuses on the ramp metering analysis conducted for Years 2010 and 2020 and the comparison between the no-metering and metering scenarios. Note that this analysis focuses on the mainline and ramps without a detailed assessment of diversion due to ramp metering. Arterial diversion will be addressed in future memoranda.

Ramp Meter Coding

The 2010 and 2020 FREQ no-metering models were updated to include simulation with ramp metering. The ramp metering parameters were coded as defined in Technical Memorandum No. 5 ("Ramp Metering Parameters and Scenarios"). A quick recap of Scenario 1 versus Scenario 2 metering is provided in Table 1.

TABLE 1
Proposed Ramp Metering Scenarios for Testing

Design Parameter	Scenario 1 – Ramp Queue Limits	Scenario 2 – Minimize Mainline Delay
GEOGRAPHIC LIMITS	All on-ramps in study area: US 101 – SF to SC I-280 – SF to I-380	Same as Scenario 1
TYPES OF METERING	All on-ramps and low-volume freeway connectors (exact connectors to be determined); no mainline metering	Same as Scenario 1
METERING RATES	Per Caltrans standards; vary by ramp	Same as Scenario 1
RAMP GEOMETRICS	Improve ramps where critical and relatively easy ("high" feasibility for improvement)	Improve ramps where appropriate and feasible ("high" or "medium" feasibility for improvement)
HOV TREATMENT	Improve ramps where critical and relatively easy ("high" feasibility for improvement)	Improve ramps where appropriate and feasible ("high" or "medium" feasibility for improvement)
QUEUE LIMITS	Limit to length of on-ramp	No limit[1]
RAMP DELAY	No specific constraint, but a function of queue limit	Same as Scenario 1
FREEWAY PERFORMANCE	No objective	50% reduction in mainline delay[2]

[1] As deemed appropriate, extended limits (e.g. beyond the ramp itself) on queue lengths and maximum delays will be specified at some locations if the unconstrained situation produces highly unreasonable queues.

[2] Percent reduction may change following initial runs and may vary by corridor, time period, and/or direction.

Source: DKS Associates, 2003

Additionally, the mainline capacity in merge and weave areas was increased by three percent where meters are engaged. This increase is based on the theory and field observations that capacity can be increased by reducing the friction at merge points. For example, without ramp metering, vehicles typically enter the freeway in platoons (typically due to an upstream signal). When this platoon of vehicles arrives at the freeway at the same time, merging/weaving operations are made more difficult because the vehicles traveling on the mainline have to accommodate this platoon of cars at the same time. However, with ramp metering, the platoons are dispersed, allowing only one or two cars to enter the traffic stream at the same time. This, in turn, causes less friction with the vehicles already on the mainline and increases segment capacity.

Also, FREQ's diversion function was engaged. As noted earlier, this analysis does not include a detailed assessment of the expected diversion and associated impacts; this analysis will be conducted in a future step. However, FREQ does include a feature to estimate the impacts of ramp-to-ramp diversion; it assumes a simplistic parallel arterial (similar to El Camino Real) along the length of the freeway corridor. While this does not provide comprehensive diversion analysis, it does provide a tool for estimating some impacts, so this diversion feature was engaged in the analysis described below.

Ramp Metering Results

The Scenario 1 and Scenario 2 metering results are presented by freeway and direction in the following sections.

US 101 Northbound (NB)

For the Scenario 1 analysis, the following improvements were assumed:

- Hillsdale eastbound on-ramp (loop) was widened to two lanes.
- The Anza ramp was lengthened by 25 vehicles.

For the Scenario 2 analysis, the improvements made for Scenario 1 were included in addition to the following improvements:

- The queue storage was doubled for the following ramps: Woodside (loop), Whipple (loop), and Hillsdale (loop).
- An additional lane was added to the Woodside (loop) on-ramp for the 2020 PM analysis only.
- The queue storage was lengthened by 50 vehicles (unless noted otherwise) for the following on-ramps: University (loop and diagonal) - 100 vehicles each, Willow (loop and diagonal), Marsh (loop and diagonal), Woodside (loop and diagonal), Whipple (loop and diagonal), Holly (loop and diagonal), Ralston (loop and diagonal), and Hillsdale (loop and diagonal) - 100 vehicles on diagonal.

Table 2 shows the results of the metering analysis for US 101 NB. Since the goal for the Scenario 2 metering was a 50% reduction in mainline delay, the 2010 PM analysis was not conducted because this goal was achieved for Scenario 1. For all analyses, the mainline delay decreases; however, a reduction of 50% on the mainline was not possible for the Scenario 2 analyses. Overall, the freeway plus ramp delay varies between –29% to +18%.

FREQ contour maps that illustrate the relative congestion patterns for each year and peak are provided at the back of this memo in Figures 1-4. The queues on the no-metering and metering contour maps can be compared to identify the impacts of ramp metering. Note that bottlenecks begin at the yellow band and the triangular area (yellow and red) shows the extent of the queue (the freeway facility is shown across the top of the figure and the time of day is shown down the left side). From the graphic output, it is easy to see the distance the queue will extend and the amount of time the queue will be in place.

TABLE 2
US 101 NB Ramp Metering Results (Without Arterial Diversion Analysis)

Year	Peak	Scenario	Mainline Delay (Veh-hrs)	% Δ in Mainline Delay	Ramp Delay (Veh-hrs)	Freeway + Ramp Delay	% Δ in Freeway + Ramp Delay	Mainline Speed
2010	AM	No Metering	2281		399	2680		56
		Metering Scenario 1	1619	**-29%**	1147	2766	3%	60
		Metering Scenario 2	1192	**-48%**	922	2114	**-21%**	62
2010	PM	No Metering	5220		693	5913		46
		Metering Scenario 1	2061	**-61%**	2135	4196	**-29%**	58
		Metering Scenario 2	n/a	n/a	n/a	n/a	n/a	n/a
2020	AM	No Metering	7581		3138	10719		40
		Metering Scenario 1	7054	**-7%**	4068	11122	4%	41
		Metering Scenario 2	6156	**-19%**	6467	12623	18%	43
2020	PM	No Metering	10514		523	11037		35
		Metering Scenario 1	9920	**-6%**	565	10485	**-5%**	36
		Metering Scenario 2	8158	**-22%**	3886	12044	9%	39

US 101 Southbound (SB)

The Poplar on-ramp was widened to two lanes for Scenarios 1 and 2. Additionally, the following improvements were also made for Scenario 2:

- The queue storage was doubled for the following on-ramps: Harney, Sierra Point, Produce, Fashion Island, Woodside, Marsh (diagonal), and Willow (loop).
- An additional lane was added to the Hillsdale (loop) on-ramp.
- The queue storage was lengthened by 50 vehicles for the following on-ramps: Bayshore, Oyster Point, San Bruno, Millbrae (loop and diagonal), Broadway, 3rd (loop and diagonal), Hillsdale (diagonal), Holly, Brittan, Whipple (loop and diagonal), Marsh (loop), Willow (diagonal) and University.

For Scenario 1, the mainline delay is reduced 11 to 60%; however, the net freeway delay increases for the PM peak. For Scenario 2, a 50% reduction in mainline delay was achieved for all scenarios. The results of the metering analysis for US 101 SB are shown in Table 3. FREQ contour maps that illustrate the relative congestion patterns for each year and peak are provided at the back of this memo in Figures 5-8.

TABLE 3
US 101 SB Ramp Metering Results (Without Arterial Diversion Analysis)

Year	Peak	Scenario	Mainline Delay (Veh-hrs)	% Δ in Mainline Delay	Ramp Delay (Veh-hrs)	Freeway + Ramp Delay	% Δ in Freeway + Ramp Delay	Mainline Speed
2010	AM	No Metering	5818		66	5884		43
		Metering Scenario 1	3550	-39%	1906	5456	-7%	51
		Metering Scenario 2	2726	-53%	3270	5996	2%	54
2010	PM	No Metering	5964		1027	6991		41
		Metering Scenario 1	5293	-11%	1875	7168	3%	43
		Metering Scenario 2	2812	-53%	5079	7891	13%	53
2020	AM	No Metering	6993		499	7492		41
		Metering Scenario 1	4868	-30%	1889	6757	-10%	47
		Metering Scenario 2	2992	-57%	2335	5327	-29%	54
2020	PM	No Metering	627		10720	11347		65
		Metering Scenario 1	253	-60%	15532	15785	39%	68
		Metering Scenario 2	n/a	n/a	n/a	n/a	n/a	n/a

I-280 Northbound (NB)

No ramp improvements were made for Scenario 1. For Scenario 2, the following modifications were made:

- The queue storage was doubled at the Sneath on-ramp
- The queue storage was lengthened by 15 vehicles at the Westborough (loop) on-ramp

The metering results for I-280 NB are shown in Table 4. Mainline delay was reduced 0 to 72% for Scenario 1 and the net freeway delay ranged from -70% to +2%. Scenario 2 metering analysis was conducted for 2020 PM only. FREQ contour maps that illustrate the relative congestion patterns for each year and peak are provided at the back of this memo in Figures 9-12.

TABLE 4
I-280 NB Ramp Metering Results (Without Arterial Diversion Analysis)

Year	Peak	Scenario	Mainline Delay (Veh-hrs)	% Δ in Mainline Delay	Ramp Delay (Veh-hrs)	Freeway + Ramp Delay	% Δ in Freeway + Ramp Delay	Mainline Speed
2010	AM	No Metering	51		0	51		68
		Metering Scenario 1	51	0%	0	51	0%	68
		Metering Scenario 2	n/a	n/a	n/a	n/a	n/a	n/a
2010	PM	No Metering	373		11	384		61
		Metering Scenario 1	257	-31%	94	351	-9%	64
		Metering Scenario 2	n/a	n/a	n/a	n/a	n/a	n/a
2020	AM	No Metering	341		0	341		60
		Metering Scenario 1	96	-72%	5	101	-70%	67
		Metering Scenario 2	n/a	n/a	n/a	n/a	n/a	n/a
2020	PM	No Metering	623		42	665		56
		Metering Scenario 1	363	-42%	314	677	2%	61
		Metering Scenario 2	304	-51%	457	761	14%	63

I-280 Southbound (SB)

No ramp improvements were made for Scenario 1 and Scenario 2 analyses were not conducted. As shown in Table 5, for the 2010 analyses and 2020 AM, the mainline delay was reduced by at least 50% for Scenario 1. However, for 2020 PM the mainline delay was only reduced by 16%. A Scenario 2 analysis was attempted; however, the ramp demands were too high and further reduction in mainline delay could not be achieved. FREQ contour maps that illustrate the relative congestion patterns for each year and peak are provided at the back of this memo in Figures 13-16.

TABLE 5
I-280 SB Ramp Metering Results(Without Arterial Diversion Analysis)

Year	Peak	Scenario	Mainline Delay (Veh-hrs)	% Δ in Mainline Delay	Ramp Delay (Veh-hrs)	Freeway + Ramp Delay	% Δ in Freeway + Ramp Delay	Mainline Speed
2010	AM	No Metering	1091		0	1091		48
		Metering Scenario 1	351	-68%	212	563	-48%	61
		Metering Scenario 2	n/a	n/a	n/a	n/a	n/a	n/a
2010	PM	No Metering	561		6	567		56
		Metering Scenario 1	163	-71%	119	282	-50%	65
		Metering Scenario 2	n/a	n/a	n/a	n/a	n/a	n/a
2020	AM	No Metering	2448		1	2449		35
		Metering Scenario 1	903	-63%	350	1253	-49%	51
		Metering Scenario 2	n/a	n/a	n/a	n/a	n/a	n/a
2020	PM	No Metering	2249		594	2843		36
		Metering Scenario 1	1888	-16%	707	2595	-9%	39
		Metering Scenario 2	n/a	n/a	n/a	n/a	n/a	n/a

Additional detail is provided in Appendix A (Sceanrio 1 and 2 Analysis Results PowerPoint Presentation).

Summary of Mainline and Ramp Impacts

Table 6 shows the percent change in delay between the no-metering and metering conditions for the mainline and the mainline plus ramp delay for each freeway/direction and scenario. The overall average, maximum and minimum delays are also shown. The Scenario 1 ramp metering analysis indicates that a decrease in mainline plus ramp delay will be experienced in the future. However, in an effort to further reduce the mainline delay, the delay at the on-ramps increased significantly, resulting in a net increase (mainline + ramp delay) for the Scenario 2 assessment.

TABLE 6
Percent Change in Mainline Delay Between No-Metering and Metering (Without Arterial Diversion Analysis)

Scenario	Metering Scenario 1		Metering Scenario 2	
	Mainline	Mainline + Ramps	Mainline	Mainline + Ramps
2010AM US101 NB	-29%	3%	-48%	-21%
2010PM US101 NB	-61%	-29%	n/a	n/a
2020AM US101 NB	-7%	4%	-19%	18%
2020PM US101 NB	-6%	-5%	-22%	9%
2010AM US101 SB	-39%	-7%	-53%	2%
2010PM US101 SB	-11%	3%	-53%	13%
2020AM US101 SB	-30%	-10%	-57%	-29%
2020PM US101 SB	-60%	39%	n/a	n/a
2010AM I-280 NB	0%	0%	n/a	n/a
2010PM I-280 NB	-31%	-9%	n/a	n/a
2020AM I-280 NB	-72%	-70%	n/a	n/a
2020PM I-280 NB	-42%	2%	-51%	14%
2010AM I-280 SB	-68%	-48%	n/a	n/a
2010PM I-280 SB	-71%	-50%	n/a	n/a
2020AM I-280 SB	-63%	-49%	n/a	n/a
2020PM I-280 SB	-16%	-9%	n/a	n/a

Origin-Destination Travel Time

An assessment of travel time was conducted for the no-metering and metering conditions to determine overall travel time (mainline plus origin on-ramp metering delay) for critical origin-destination (OD) pairs. The OD pairs were selected for each freeway/direction based on corridor congestion and logical termini. Table 7 outlines the corridor extents for each OD pair. Note that only two OD pairs were assessed for I-280 because of the short corridor length and localized congestion (i.e., only one bottleneck for the corridor or the bottlenecks are spaced very closely).

TABLE 7. Description of OD Pairs by Freeway/Direction

Freeway/Direction	Pair 1	Pair 2	Pair 3	Pair 4
US 101 NB	Corridor - mainline south of University to mainline north of Harney (26.6 miles)	Willow Loop on to Holly CD off (6.5 mi)	Marsh Loop on to SFO off (15.2 miles)	Third Loop on to Oyster Point off (9.1miles)
US 101 SB	Corridor - Mainline north of Harney to south of University (26.7 miles)	Holly on to Willow off (5.9 miles)	SFO on to Marsh off (15.6 miles)	Oyster Point on to Third off (9.1 miles)
I-280 NB	Corridor - mainline south of Sneath to mainline north of Knowles (6.3 miles)	Sneath on to John Daly off (5.0 miles)	N/A	N/A
I-280 SB	Corridor - mainline north of John Daly to mainline south of Sneath (6.3 miles)	John Daly on to Sneath off (5.7 mi)	N/A	N/A

Tables 8 through 11 show the change in travel time (in minutes) for each OD pair for each freeway/direction. Overall, a majority of the travel times decrease or remain the same with ramp metering.

TABLE 8
US 101 NB OD Travel Time Results (Without Arterial Diversion Analysis)

Year	Peak	Scenario	Pair 1: Mainline end to end		Pair 2: Willow to Holly		Pair 3: Marsh to SFO		Pair 4: Third to Oyster Point	
			Travel Time	Ramp Delay	Travel Time	Ramp Delay	Travel Time	Ramp Delay	Travel Time	Ramp Delay
2010	AM	No Metering	29		6		15		8	
		Metering Scenario 1	**28**	1	**7**	1	15	1	8	0
		Metering Scenario 2	**27**	0	6	0	**14**	0	8	0
2010	PM	No Metering	31		6		19		8	
		Metering Scenario 1	**30**	1	6	0	19	2	8	0
		Metering Scenario 2	n/a	-	n/a	-	n/a	-	n/a	-
2020	AM	No Metering	36		9		22		8	
		Metering Scenario 1	**33**	0	**10**	2	**21**	2	8	0
		Metering Scenario 2	**30**	0	**10**	3	**23**	5	**9**	0
2020	PM	No Metering	53		26		32		8	
		Metering Scenario 1	53	0	26	0	**34**	2	8	0
		Metering Scenario 2	**46**	0	**25**	3	**39**	7	8	0

TABLE 9
US 101 SB OD Travel Time Results (Without Arterial Diversion Analysis)

Year	Peak	Scenario	Pair 1: Mainline end to end		Pair 2: Holly to Willow		Pair 3: SFO to Marsh		Pair 4: Oyster Point to Third	
			Travel Time	Ramp Delay	Travel Time	Ramp Delay	Travel Time	Ramp Delay	Travel Time	Ramp Delay
2010	AM	No Metering	34		11		17		9	
		Metering Scenario 1	**32**	0	**10**	0	17	0	9	0
		Metering Scenario 2	**30**	0	**10**	1	**16**	0	**8**	0
2010	PM	No Metering	51		31		34		8	
		Metering Scenario 1	**49**	0	31	1	**31**	0	**12**	4
		Metering Scenario 2	**36**	0	**19**	1	**18**	0	**15**	7
2020	AM	No Metering	37		5		27		19	
		Metering Scenario 1	**36**	0	5	0	**25**	0	**18**	0
		Metering Scenario 2	**34**	0	5	0	**24**	0	**15**	0
2020	PM	No Metering	26		6		14		8	
		Metering Scenario 1	**24**	0	**11**	6	14	0	8	0
		Metering Scenario 2	n/a	-	n/a	-	n/a	-	n/a	-

TABLE 10
I-280 NB OD Travel Time Results (Without Arterial Diversion Analysis)

Year	Peak	Scenario	Pair 1: Mainline end to end		Pair 2: Sneath to John Daly	
			Travel Time	Ramp Delay	Travel Time	Ramp Delay
2010	AM	No Metering	6		5	
		Metering Scenario 1	6	0	5	0
		Metering Scenario 2	n/a	-	n/a	-
2010	PM	No Metering	7		5	
		Metering Scenario 1	**6**	0	5	0
		Metering 2 with diversion	n/a	-	n/a	-
2020	AM	No Metering	6		5	
		Metering Scenario 1	6	0	5	0
		Metering Scenario 2	n/a	-	n/a	-
2020	PM	No Metering	7		5	
		Metering Scenario 1	**6**	0	**7**	2
		Metering Scenario 2	**6**	0	**8**	3

TABLE 11
I-280 SB OD Travel Time Results (Without Arterial Diversion Analysis)

Year	Peak	Scenario	Pair 1: Mainline end to end		Pair 2: John Daly to Sneath	
			Travel Time	Ramp Delay	Travel Time	Ramp Delay
2010	AM	No Metering	7		7	
		Metering Scenario 1	7	0	**6**	0
		Metering Scenario 2	n/a	-	n/a	-
2010	PM	No Metering	9		8	
		Metering Scenario 1	**6**	0	**6**	0
		Metering Scenario 2	n/a	-	n/a	-
2020	AM	No Metering	9		8	
		Metering Scenario 1	**8**	0	**7**	0
		Metering Scenario 2	n/a	-	n/a	-
2020	PM	No Metering	17		14	
		Metering Scenario 1	**16**	1	14	0
		Metering Scenario 2	n/a	-	n/a	-

Average and Maximum Ramp Delay Due to Ramp Metering

The average and maximum ramp delays due to ramp metering were calculated by freeway/direction and scenario. Table 12 shows the average ramp delay and Table 13 shows the maximum ramp delay. It should be noted that for some scenarios the average ramp delay is zero. Ramps downstream of bottlenecks will be metered at the demand rate, so no queuing (delay) is expected. In some cases, ramp meters were activated for only a portion of the peak period due to excessive queuing beyond the ramp meter. The average delay is calculated only for those periods where there is some queue (i.e., zeros were not averaged into the overall ramp delay.

TABLE 12
Average Ramp Delay (Minutes) Due to Ramp Metering by Freeway/Direction (Without Arterial Diversion Analysis)

Year	Peak	Scenario	101 NB	101 SB	280 NB	280 SB
2010	AM	1	3	4	0	4
		2	5	7	n/a	n/a
2010	PM	1	4	4	2	7
		2	n/a	9	n/a	n/a
2020	AM	1	3	3	0	5
		2	10	3	n/a	n/a
2020	PM	1	3	6	4	9
		2	10	n/a	6	n/a

TABLE 13
Maximum Ramp Delay (Minutes) Due to Ramp Metering by Freeway/Direction (Without Arterial Diversion Analysis)

Year	Peak	Scenario	101 NB	101 SB	280 NB	280 SB
2010	AM	1	10	13	0	27
		2	23	24	n/a	n/a
2010	PM	1	26	11	8	28
		2	n/a	31	n/a	n/a
2020	AM	1	12	12	1	28
		2	27	15	n/a	n/a
2020	PM	1	8	52	16	31
		2	39	n/a	17	n/a

Note: Maximum ramp delay also includes delay on the ramps due to mainline congestion. Not all delay is caused by ramp meters, particularly for the longer maximum delays listed in the table.

Conclusion

The results of the 2010 and 2020 metering analysis indicate that ramp metering will be of benefit in managing traffic congestion on the freeway in the Peninsula Corridor. As indicated in Table 6, there is a balance between mainline delay and ramp delay that will provide an overall decrease in congestion along the corridor. While a few scenarios suggest only marginal or negative system benefit of ramp metering, the majority of the scenarios indicate an overall positive benefit, suggesting that ramp metering can be a useful tool for improving traffic operations.

Metering was particularly effective in the Scenario 1 investigations, the 2010 analyses, for I-280. In general, these findings are consistent with the expectations for ramp metering, which is most effective at moderate levels of congestion. Ramp metering was also effective in the shoulder hours (as opposed to the "peak of the peak") in the congested scenarios. The benefits of ramp metering in less congested scenarios means that the strategy might be complementary to other operational strategies or modest capital improvements. Ramp metering could also be used as an incident management strategy, to control freeway flow during incidents.

While the specifics of the metering strategies would have to be refined in the field (once the future traffic demands actually occur), the FREQ analysis suggest that ramp metering can be effective for improving freeway operations in a range of scenarios that represent likely future traffic conditions. These findings need to be validated with the results of the diversion analysis, which will be undertaken in the next phase of the project.

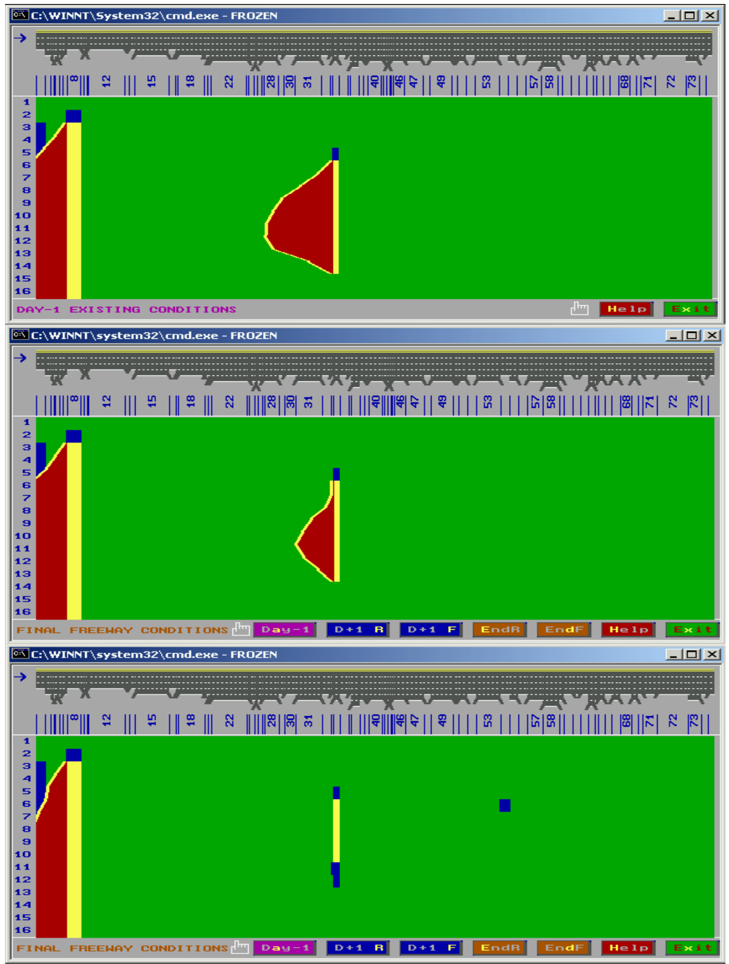
Next Steps

A diversion analysis will be conducted using the EMME/2 travel demand modeling software. The ramp meter delays derived from the FREQ model will be used as an additional input to the travel demand model. The diversion due to the delay at the ramp meters and impacts to surface streets will then be assessed and documented.

No Metering

Scenario 1

Scenario 2



Free-flow conditions where V/C < 0.9

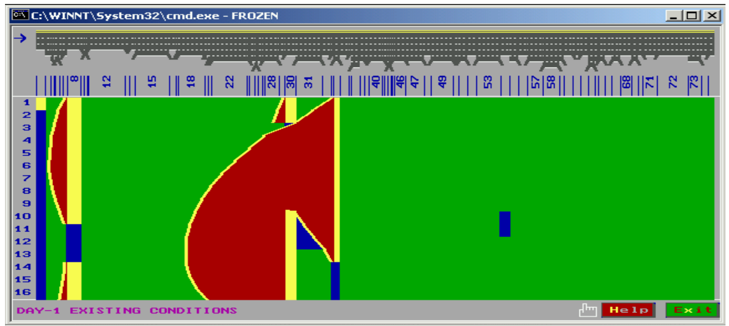
Near-capacity conditions where 0.9 <= V/C < 1.00

Bottleneck where V/C = 1.00

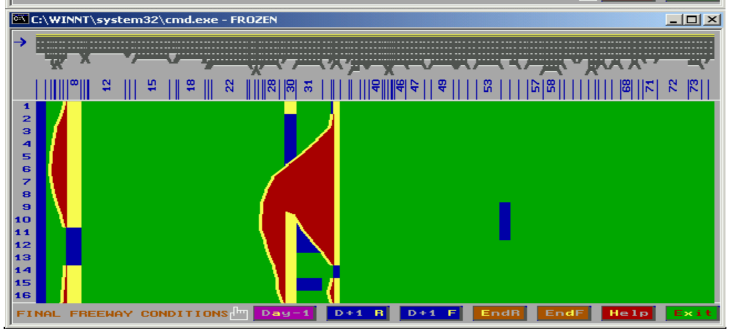
Congested-flow conditions upstream of bottleneck

FIGURE 1. US 101 NB 2010 AM Peak Contour Maps

No Metering



Scenario 1



Scenario 2

No need for action - Scenario 1 eliminates at least 50% of mainline delay

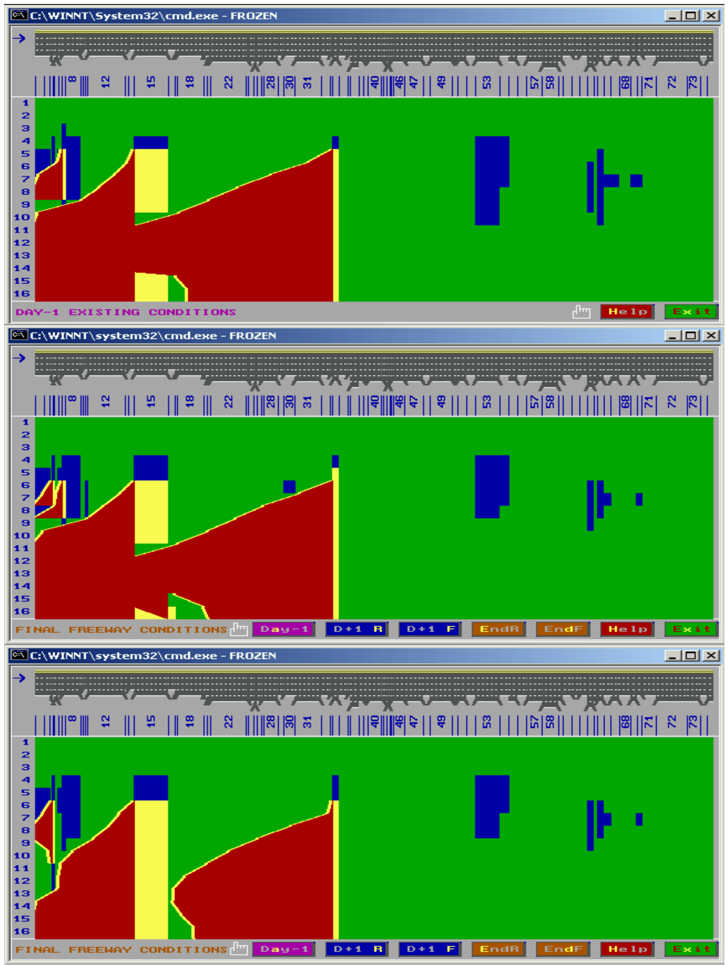
(green)	Free-flow conditions where V/C < 0.9
(blue)	Near-capacity conditions where 0.9 <= V/C < 1.00
(yellow)	Bottleneck where V/C = 1.00
(red)	Congested-flow conditions upstream of bottleneck

FIGURE 2. US 101 NB 2010 PM Peak Contour Maps

No Metering

Scenario 1

Scenario 2



Free-flow conditions where V/C < 0.9

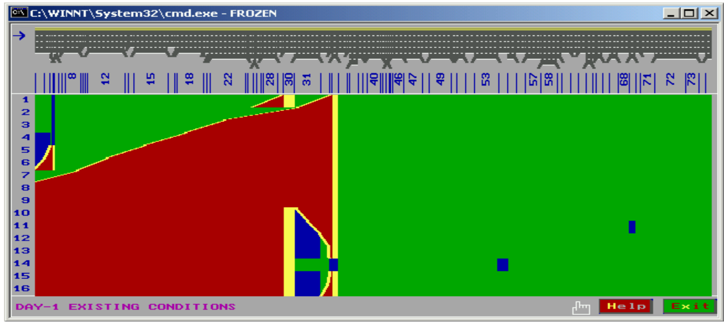
Near-capacity conditions where 0.9 <= V/C < 1.00

Bottleneck where V/C = 1.00

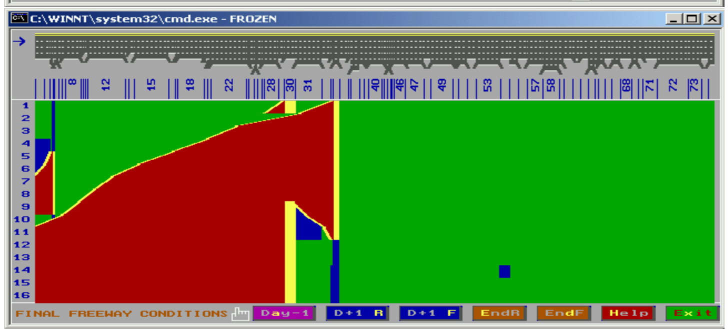
Congested-flow conditions upstream of bottleneck

FIGURE 3. US 101 NB 2020 AM Peak Contour Maps

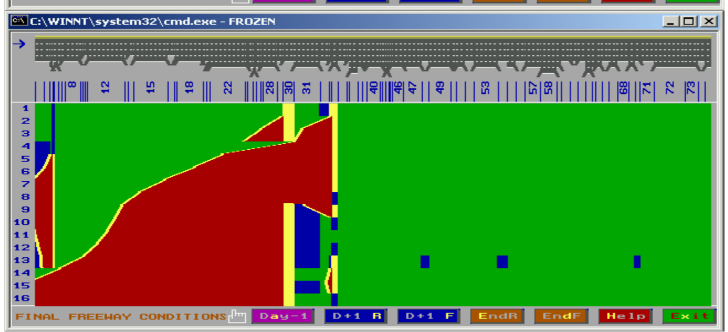
No Metering



Scenario 1



Scenario 2



Free-flow conditions where V/C < 0.9

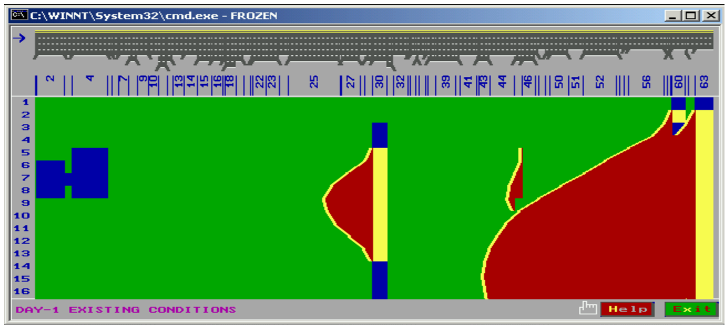
Near-capacity conditions where 0.9 <= V/C < 1.00

Bottleneck where V/C = 1.00

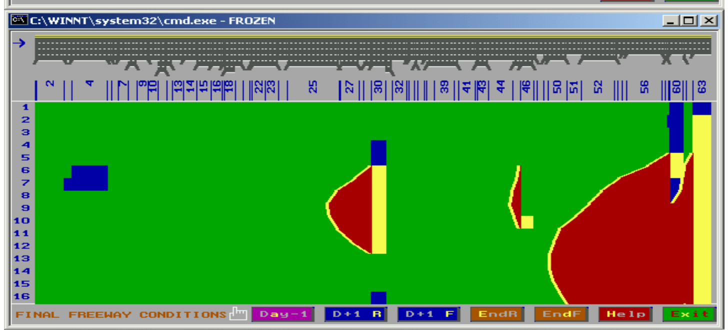
Congested-flow conditions upstream of bottleneck

FIGURE 4. US 101 NB 2020 PM Peak Contour Maps

No Metering



Scenario 1



Scenario 2

Free-flow conditions where V/C < 0.9

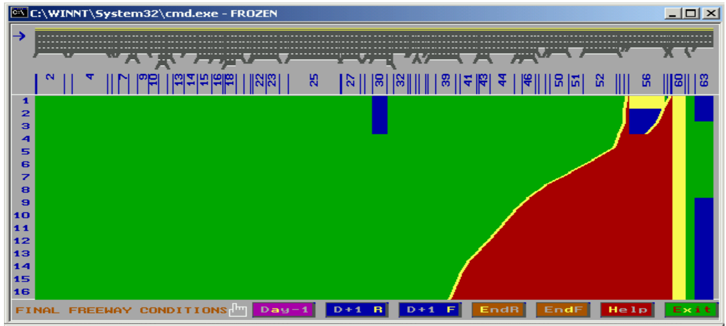
Near-capacity conditions where 0.9 <= V/C < 1.00

Bottleneck where V/C = 1.00

Congested-flow conditions upstream of bottleneck

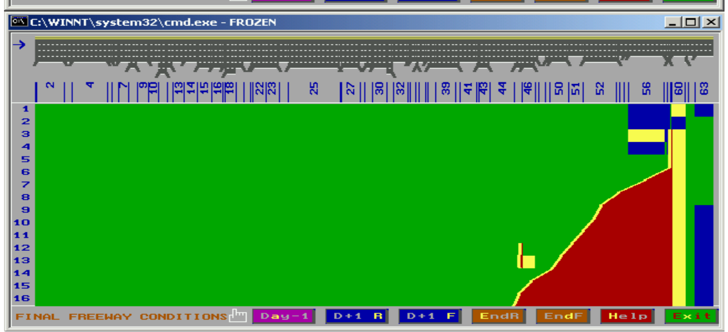
FIGURE 5. US 101 SB 2010 AM Peak Contour Maps

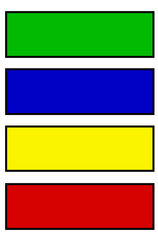
No Metering



Scenario 1

Scenario 2





Free-flow conditions where V/C < 0.9

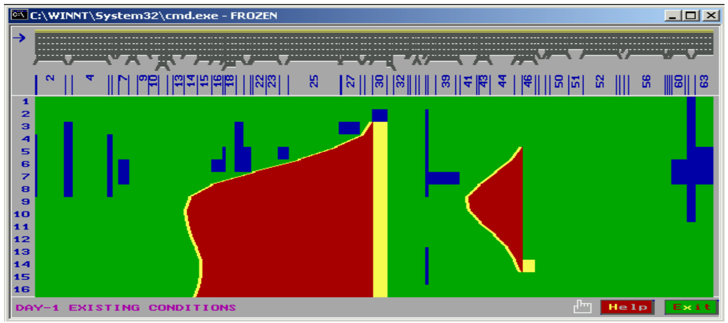
Near-capacity conditions where 0.9 <= V/C < 1.00

Bottleneck where V/C = 1.00

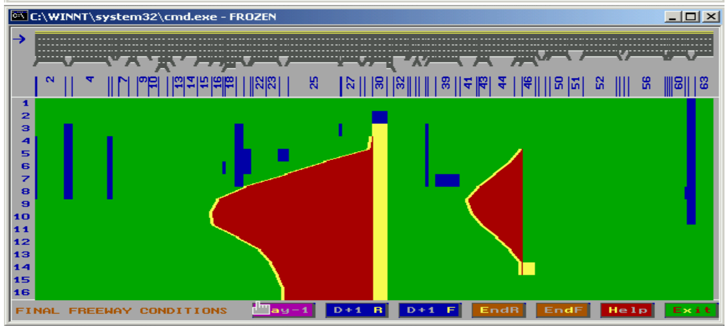
Congested-flow conditions upstream of bottleneck

FIGURE 6. US 101 SB 2010 PM Peak Contour Maps

No Metering



Scenario 1



Scenario 2

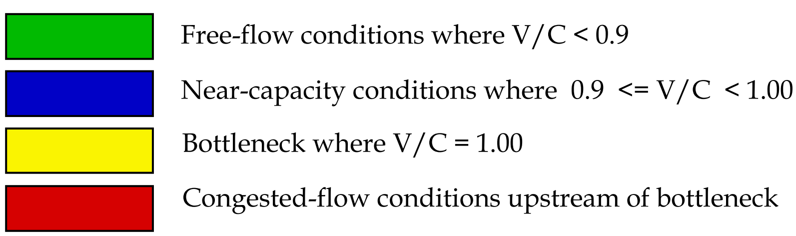
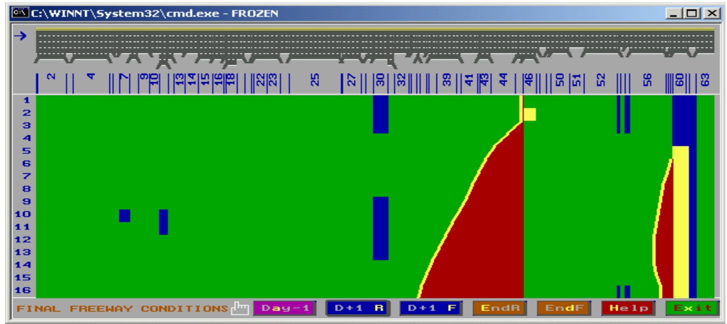
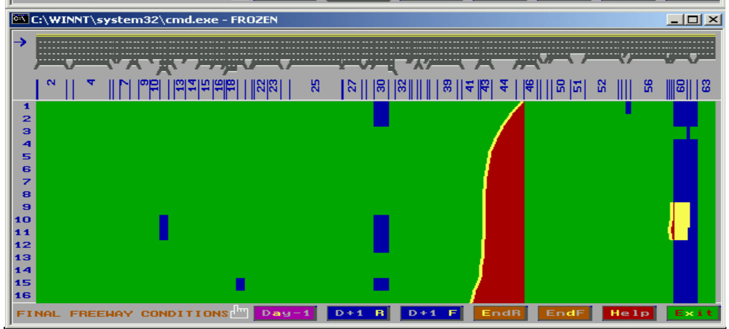


FIGURE 7. US 101 SB 2020 AM Peak Contour Maps

No Metering



Scenario 1



Scenario 2

No need for action - Scenario 1 eliminates at least 50% of mainline delay

Free-flow conditions where V/C < 0.9

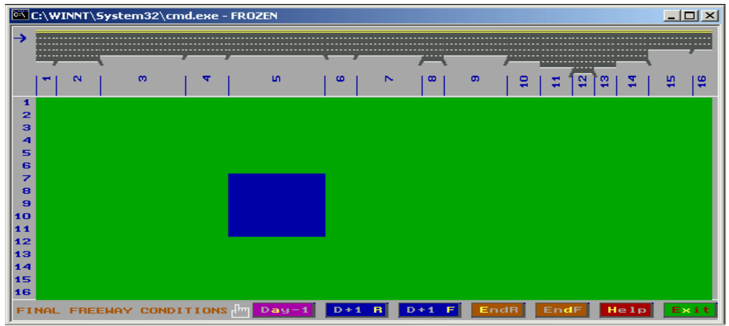
Near-capacity conditions where 0.9 <= V/C < 1.00

Bottleneck where V/C = 1.00

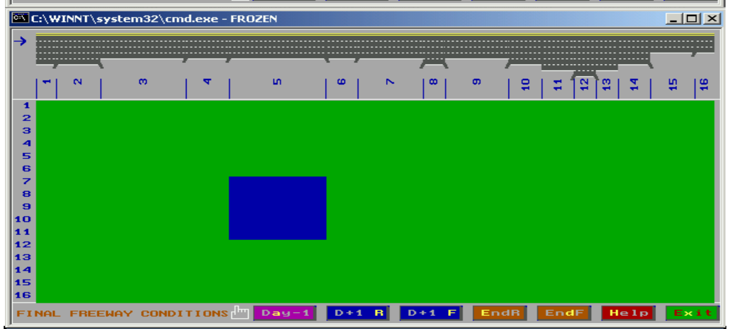
Congested-flow conditions upstream of bottleneck

FIGURE 8. US 101 SB 2020 PM Peak Contour Maps

No Metering



Scenario 1



Scenario 2

No need for action - no delay

Free-flow conditions where V/C < 0.9

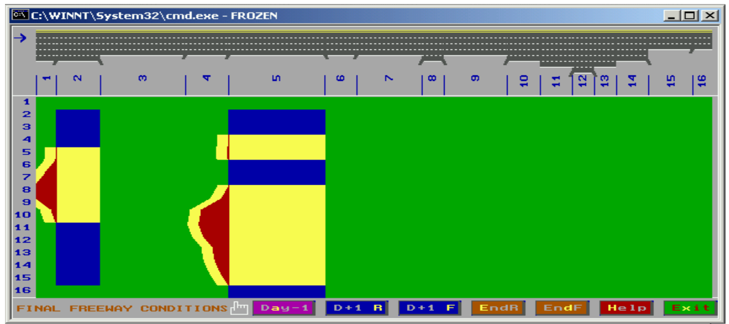
Near-capacity conditions where 0.9 <= V/C < 1.00

Bottleneck where V/C = 1.00

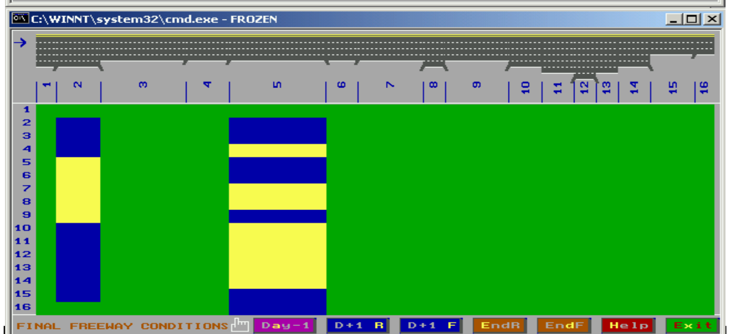
Congested-flow conditions upstream of bottleneck

FIGURE 9. I-280 NB 2010 AM Peak Contour Maps

No Metering



Scenario 1



Scenario 2

No need for action - no delay

Free-flow conditions where V/C < 0.9

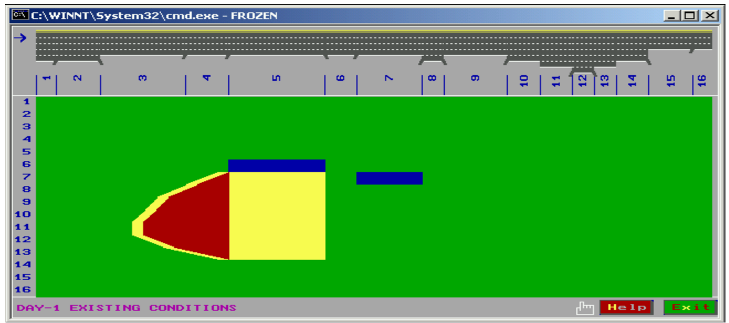
Near-capacity conditions where 0.9 <= V/C < 1.00

Bottleneck where V/C = 1.00

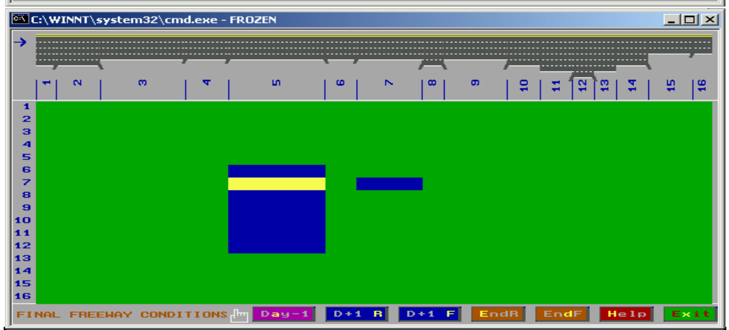
Congested-flow conditions upstream of bottleneck

FIGURE 10. I-280 NB 2010 PM Peak Contour Maps

No Metering



Scenario 1



Scenario 2

No need for action - no delay

Free-flow conditions where V/C < 0.9

Near-capacity conditions where 0.9 <= V/C < 1.00

Bottleneck where V/C = 1.00

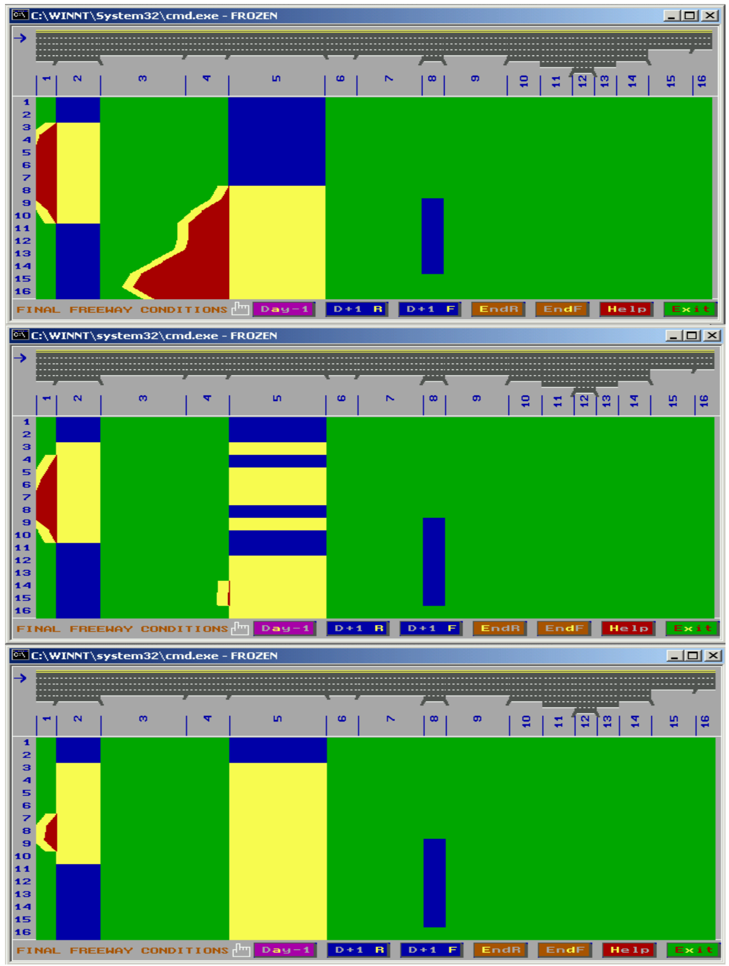
Congested-flow conditions upstream of bottleneck

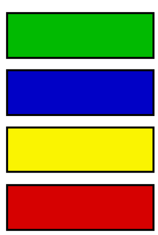
FIGURE 11. I-280 NB 2020 AM Peak Contour Maps

No Metering

Scenario 1

Scenario 2





Free-flow conditions where V/C < 0.9

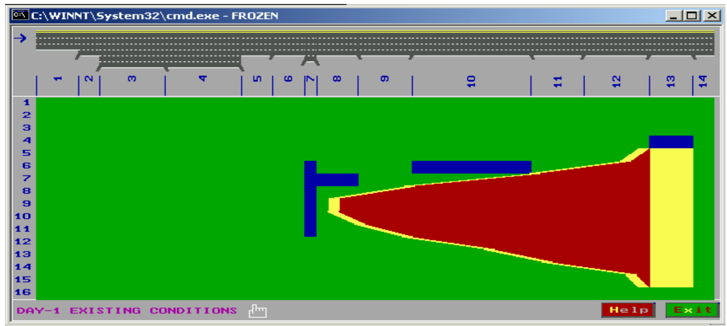
Near-capacity conditions where 0.9 <= V/C < 1.00

Bottleneck where V/C = 1.00

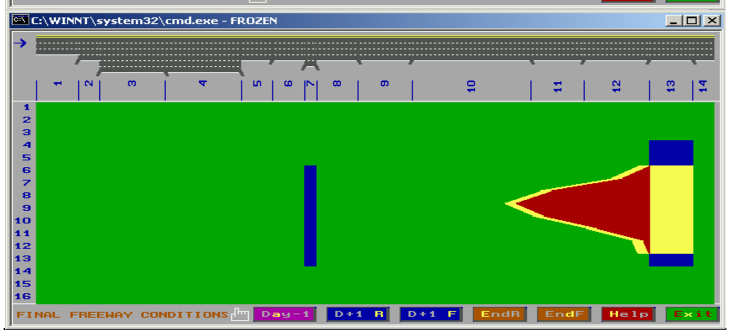
Congested-flow conditions upstream of bottleneck

FIGURE 12. I-280 NB 2020 PM Peak Contour Maps

No Metering



Scenario 1



Scenario 2

No need for action - Scenario 1 eliminates at least 50% of mainline delay

Free-flow conditions where V/C < 0.9

Near-capacity conditions where 0.9 <= V/C < 1.00

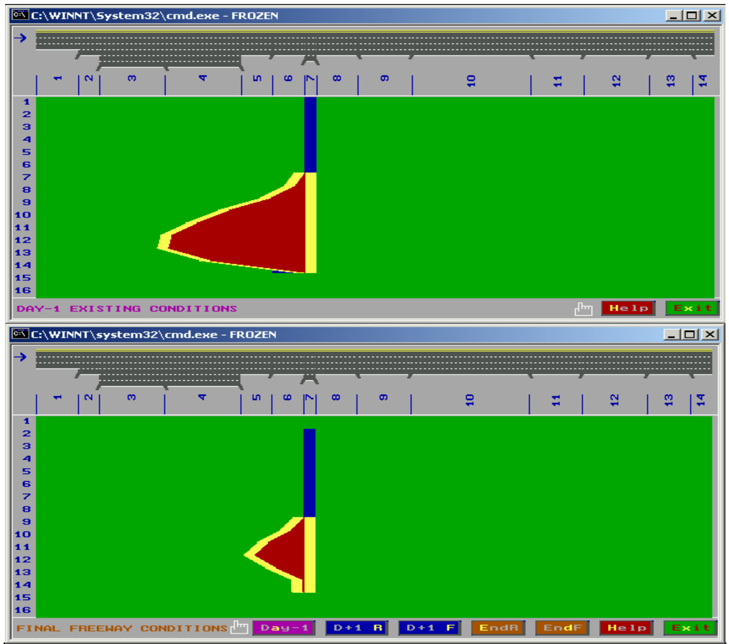
Bottleneck where V/C = 1.00

Congested-flow conditions upstream of bottleneck

FIGURE 13. I-280 SB 2010 AM Peak Contour Maps

No Metering

Scenario 1



Scenario 2

No need for action - Scenario 1 eliminates at least 50% of mainline delay

Free-flow conditions where V/C < 0.9

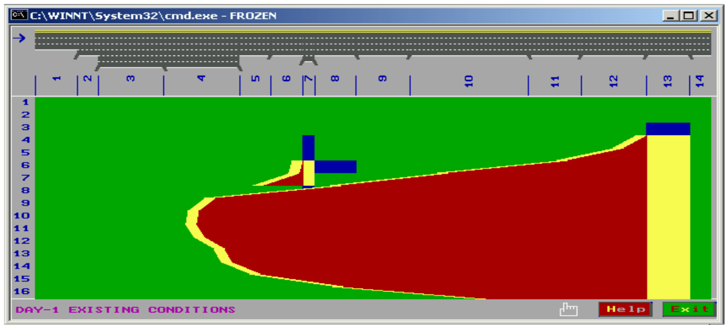
Near-capacity conditions where 0.9 <= V/C < 1.00

Bottleneck where V/C = 1.00

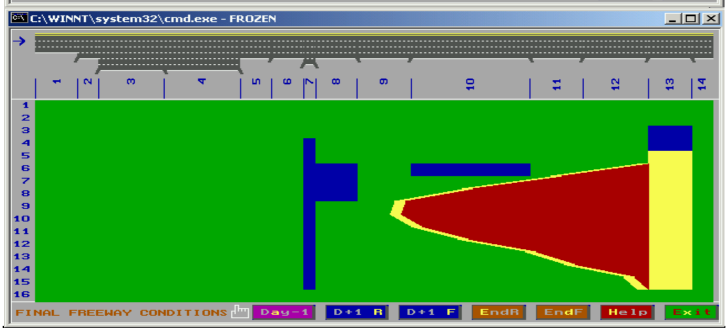
Congested-flow conditions upstream of bottleneck

FIGURE 14. I-280 SB 2010 PM Peak Contour Maps

No Metering

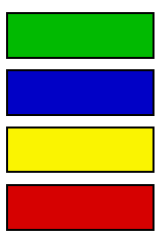


Scenario 1



Scenario 2

No need for action - Scenario 1 eliminates at least 50% of mainline delay



Free-flow conditions where V/C < 0.9

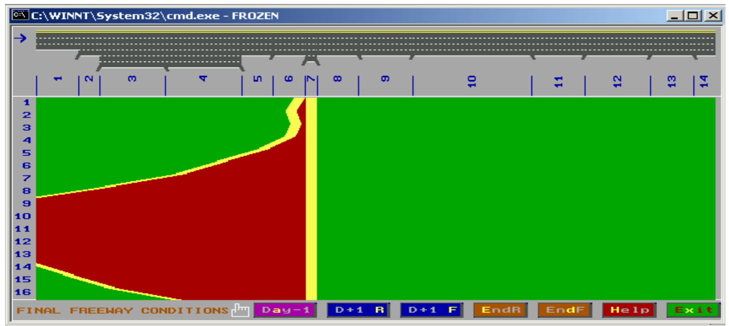
Near-capacity conditions where 0.9 <= V/C < 1.00

Bottleneck where V/C = 1.00

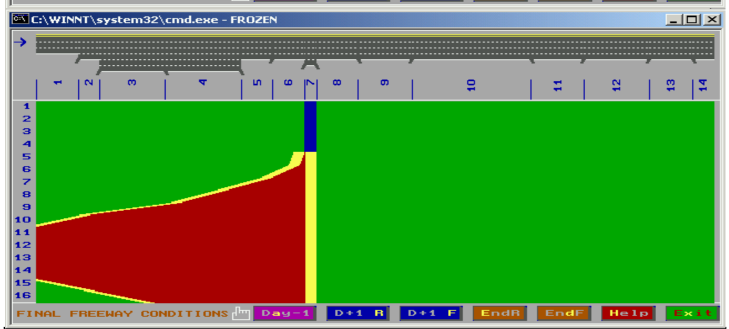
Congested-flow conditions upstream of bottleneck

FIGURE 15. I-280 SB 2020 AM Peak Contour Maps

No Metering



Scenario 1



Scenario 2

No action can be taken - ramp demands too high

Free-flow conditions where V/C < 0.9

Near-capacity conditions where 0.9 <= V/C < 1.00

Bottleneck where V/C = 1.00

Congested-flow conditions upstream of bottleneck

FIGURE 16. I-280 SB 2020 PM Peak Contour Maps

Appendix A –Scenario 1 & 2 Analysis Results Powerpoint Presentation

Peninsula Corridor Ramp Metering Study

Task 7:
Conduct Freeway Operations Analysis
(Proposed Metering Scenarios)

December 8, 2003

DKS Associates
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CH2MHILL

Outline

- **Coding Approach**
  - Scenario 1 versus Scenario 2
  - Adjust mainline capacities
- **Preliminary Results**
  - Geometry modifications
  - Freeway operations/congestion
  - Origin-Destination travel times
  - Typical ramp delays
- **Discussion**
- **Next Steps**

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Metering 2010/2020 Coding

- **Modified No Metering Files for**
  - Scenario 1 - Limited Metering
  - Scenario 2 - Expanded Metering
- **3 types of improvements:**
  - Add HOV priority lane
  - Add mixed-flow lane at meter (for throughput)
  - Add storage
- **Recommendation based on:**
  - Feasibility
  - Potential benefits/need
  - Programmed/planned improvements

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Scenario 1 - Limited Metering

- **Limited queues**
  - Length of on-ramp and exclusive right-turn lane storage
- **Minimize ramp capital improvements**
  - Only where critical and relatively easy
- **Performance objective**
  - Minimize disruption to local streets

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Scenario 2 – Expanded Metering

- **Extended queues**
  – Allow to extend beyond ramp "within reason"
- **More extensive ramp capital improvements**
  – Where feasible and beneficial
- **Performance objective**
  – Reduce mainline delay

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Scenario Comparison

Design Parameter	Scenario 1 – Limited	Scenario 2 – Expanded
GEOGRAPHIC LIMITS	All on-ramps in study area: US 101 – SF to SC I-280 – SF to I-380	Same as Scenario 1
TYPES OF METERING	All on-ramps and low -volume freeway connectors (exact connectors t o be determined); no mainline metering	Same as Scenario 1
METERING RATES	Per Caltrans standards; vary by ramp	Same as Scenario 1
RAMP GEOMETRICS	Improve ramps where critical and relatively easy (“high” feasibility for improvement)	Improve ramps where appropriate and feasible (“high” or “medium” feasibility for improvement)
HOV TREATMENT	Improve ramps where critical and relatively easy (“high” feasibility for improvement)	Improve ramps where appropriate and feasible (“high” or “medium” feasibility for improvement)
QUEUE LIMITS	Limit to length of on -ramp	No limit
RAMP DELAY	No specific constraint, but a function of queue limit	Same as Scenario 1
FREEWAY PERFORMANCE	No objective	50% reduction in mainline delay

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Freeway Capacity

- **Adjusted mainline capacity due to metering**
  - Merge areas
  - Weaving areas
- **Assumed 3% capacity increase**

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Scenario 1 - Ramp Improvements

- NB US 101 Hillsdale EB on (loop) - widened to two lanes
- NB US 101 Anza - lengthened ramp by 25 vehicles
- SB US 101 Poplar on - widened to two lanes

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Overall Scenario 1 Results - NB US 101

- Mainline delay reduced 6 to 61%
- Ramp delay increases
- Net freeway delay -29% to +4%

Year	Peak	Scenario	Mainline Delay (Veh-hrs)	% Δ in Mainline Delay	Ramp Delay (Veh-hrs)	Freeway + Ramp Delay	% Δ in Freeway + Ramp Delay	Mainline Speed
2010	AM	No Metering	2281		399	2680		56
		Metering 1 with diversion	1619	-29%	1147	2766	3%	60
2010	PM	No Metering	5220		693	5913		46
		Metering 1 with diversion	2061	-61%	2135	4196	-29%	58
2020	AM	No Metering	7581		3138	10719		40
		Metering 1 with diversion	7054	-7%	4068	11122	4%	41
2020	PM	No Metering	10514		523	11037		35
		Metering 1 with diversion	9920	-6%	565	10485	-5%	36

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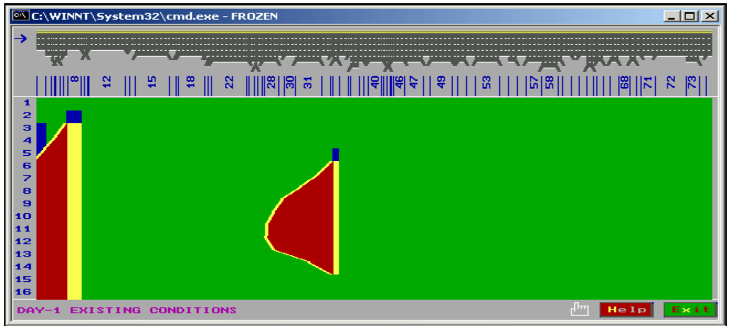
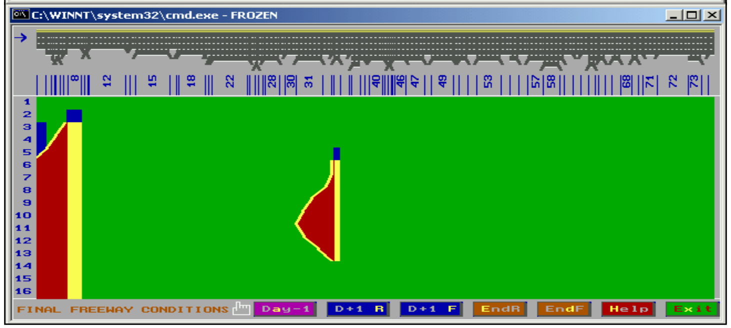
2010 NB US 101 AM Peak

No Metering



Scenario 1



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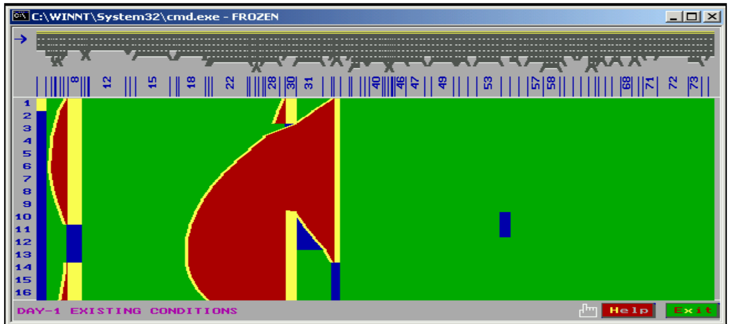
2010 NB US 101 PM Peak

No Metering



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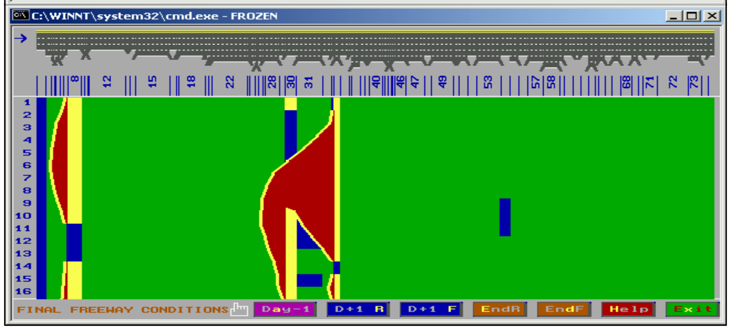

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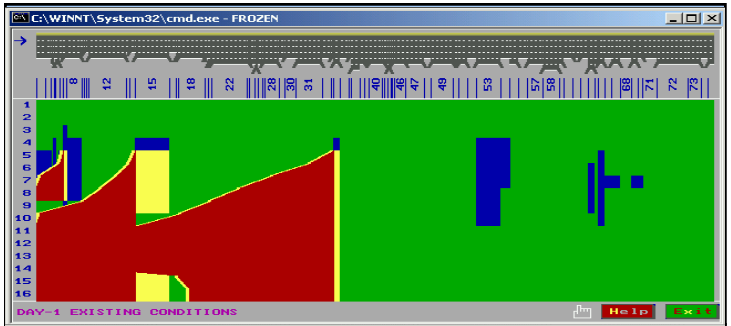
2020 NB US 101 AM Peak

No Metering



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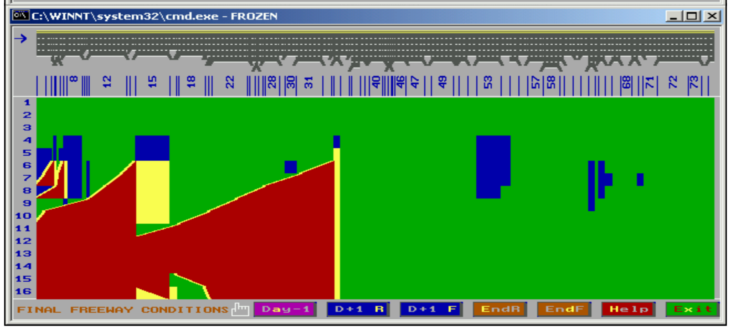
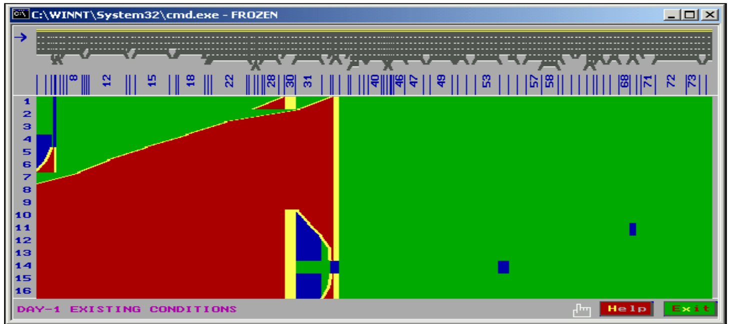
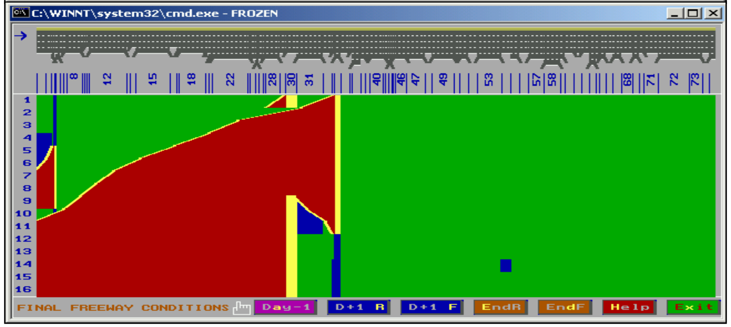


2020 NB US 101 PM Peak

No Metering



Scenario 1



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Overall Scenario 1 Results - SB US 101

- No metering with diversion for PM
- Mainline delay reduced 11 to 60%
- Net freeway delay decreases in AM peak; increases in PM peak

Year	Peak	Scenario	Mainline Delay (Veh-hrs)	% Δ in Mainline Delay	Ramp Delay (Veh-hrs)	Freeway + Ramp Delay	% Δ in Freeway + Ramp Delay	Mainline Speed
2010	AM	No Metering	5818		66	5884		43
		Metering 1 with diversion	3550	-39%	1906	5456	-7%	51
2010	PM	No Metering	5964		1027	6991		41
		Metering 1 with diversion	5293	-11%	1875	7168	3%	43
2020	AM	No Metering	6993		499	7492		41
		Metering 1 with diversion	4868	-30%	1889	6757	-10%	47
2020	PM	No Metering	627		10720	11347		65
		Metering 1 with diversion	253	-60%	15532	15785	39%	68

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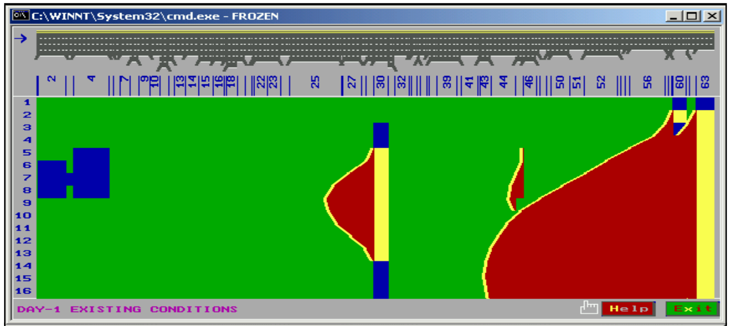
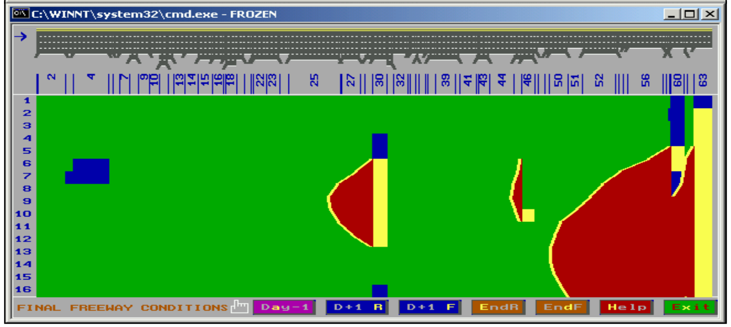
2010 SB US 101 AM Peak

No Metering



Scenario 1



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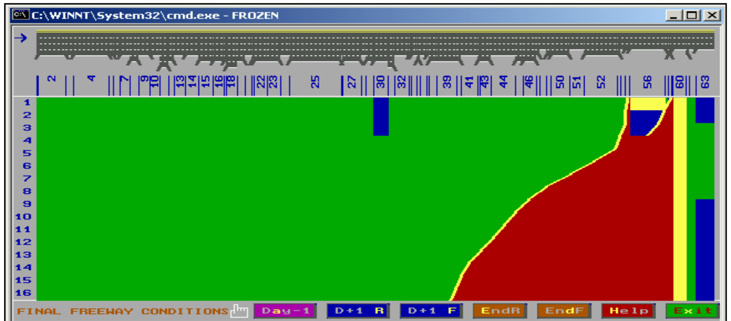
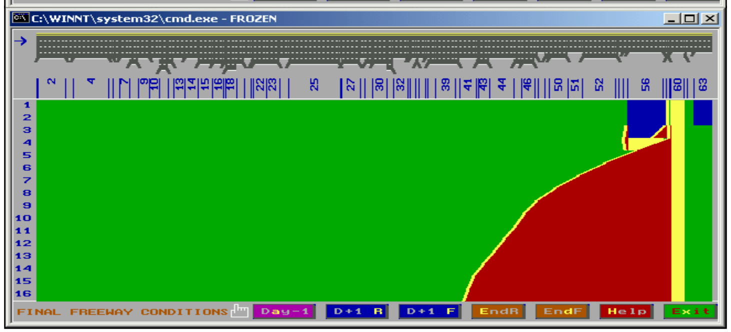
2010 SB US 101 PM Peak

No Metering



Scenario 1



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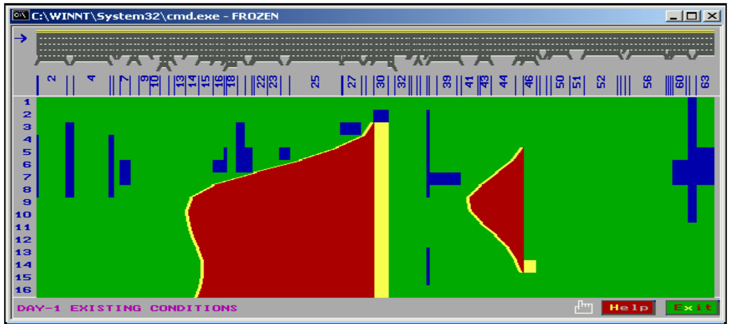
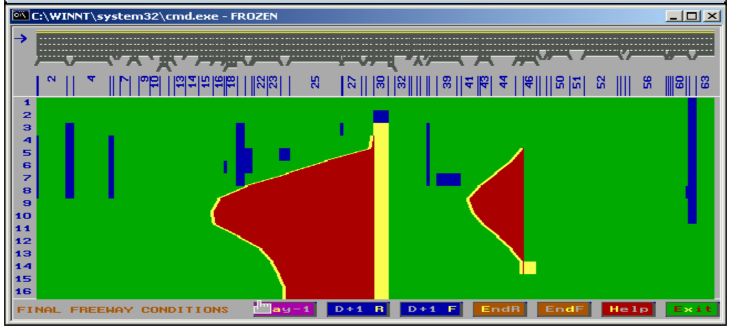
2020 SB US 101 AM Peak

No Metering



Scenario 1



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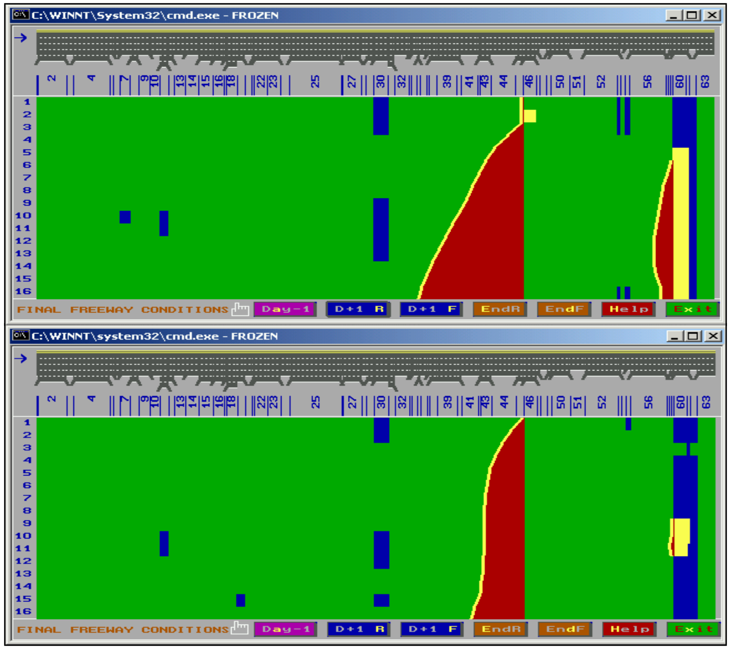
2020 SB US 101 PM Peak

No Metering

Scenario 1



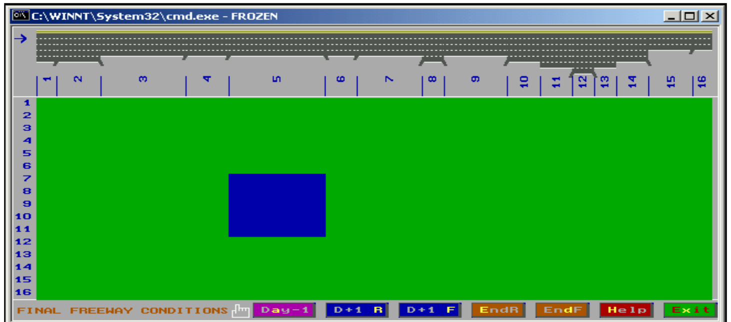
Overall Scenario 1 Results - NB I-280

- No metering with diversion for 2010 AM &PM and 2020 PM
- Mainline delay reduced 0 to 72%
- Net freeway delay -70% to +2%

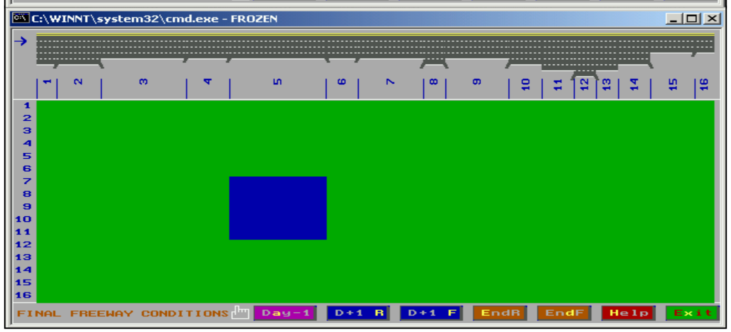
Year	Peak	Scenario	Mainline Delay (Veh-hrs)	% Δ in Mainline Delay	Ramp Delay (Veh-hrs)	Freeway + Ramp Delay	% Δ in Freeway + Ramp Delay	Mainline Speed
2010	AM	No Metering	51		0	51		68
		Metering 1 with diversion	51	0%	0	51	0%	68
2010	PM	No Metering	373		11	384		61
		Metering 1 with diversion	257	-31%	94	351	-9%	64
2020	AM	No Metering	341		0	341		60
		Metering 1 with diversion	96	-72%	5	101	-70%	67
2020	PM	No Metering	623		42	665		56
		Metering 1 with diversion	363	-42%	314	677	2%	61

2010 NB I-280 AM Peak

No Metering

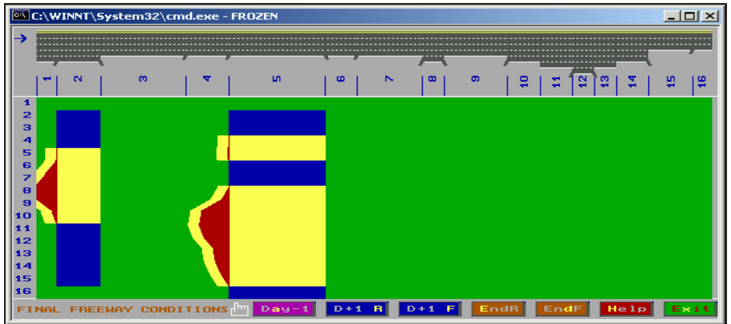


Scenario 1



2010 NB I-280 PM Peak

No Metering



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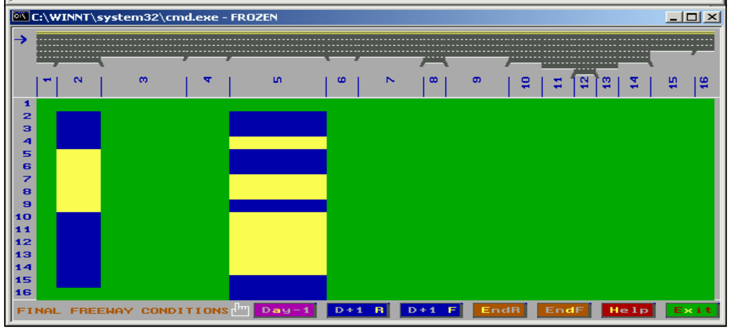

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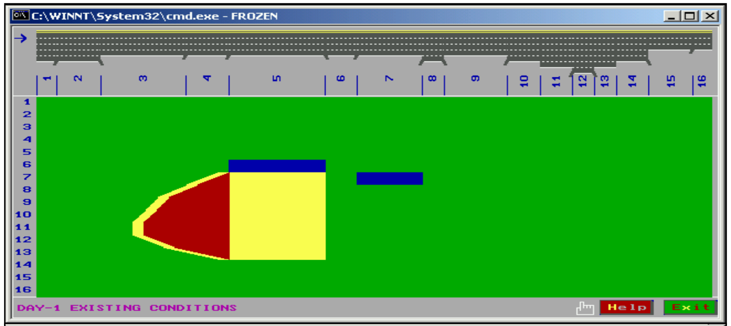
2020 NB I-280 AM Peak

No Metering



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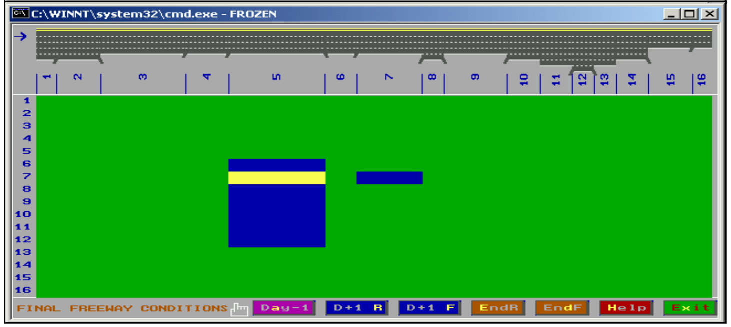

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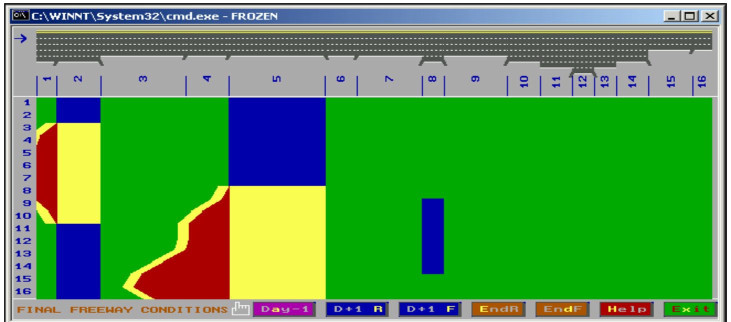
2020 NB I-280 PM Peak

No Metering



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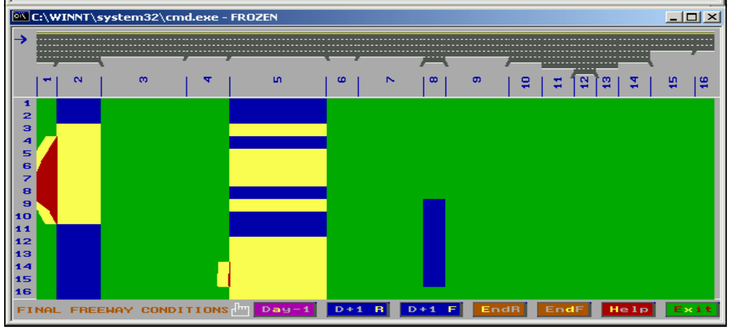

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Overall Scenario 1 Results - SB I-280

- No metering with diversion for 2020 PM
- Mainline delay decreases significantly except 2020 PM
- Net freeway delay reduced 9 to 50%

Year	Peak	Scenario	Mainline Delay (Veh-hrs)	% Δ in Mainline Delay	Ramp Delay (Veh-hrs)	Freeway + Ramp Delay	% Δ in Freeway + Ramp Delay	Mainline Speed
2010	AM	No Metering	1091		0	1091		48
		Metering 1 with diversion	351	-68%	212	563	-48%	61
2010	PM	No Metering	561		6	567		56
		Metering 1 with diversion	163	-71%	119	282	-50%	65
2020	AM	No Metering	2448		1	2449		35
		Metering 1 with diversion	903	-63%	350	1253	-49%	51
2020	PM	No Metering	2249		594	2843		36
		Metering 1 with diversion	1888	-16%	707	2595	-9%	39

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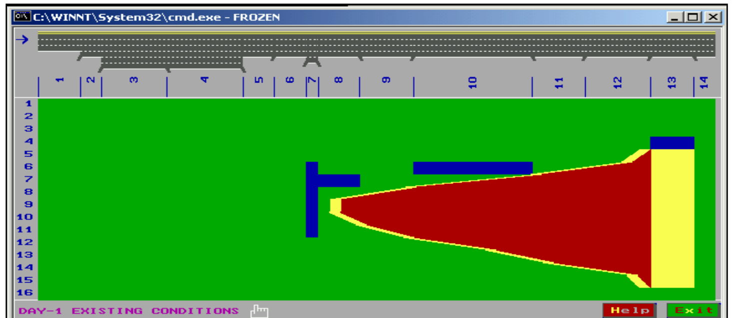
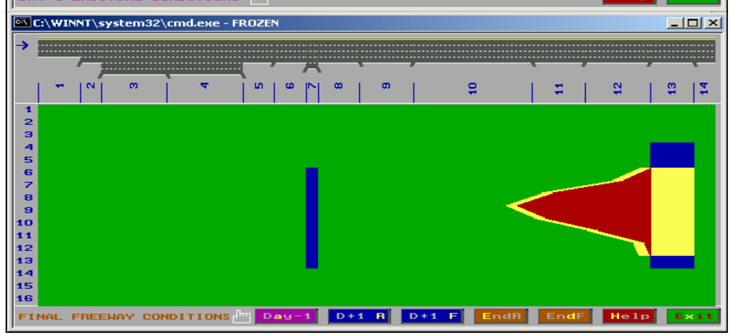
2010 SB 280 AM Peak

No Metering



Scenario 1



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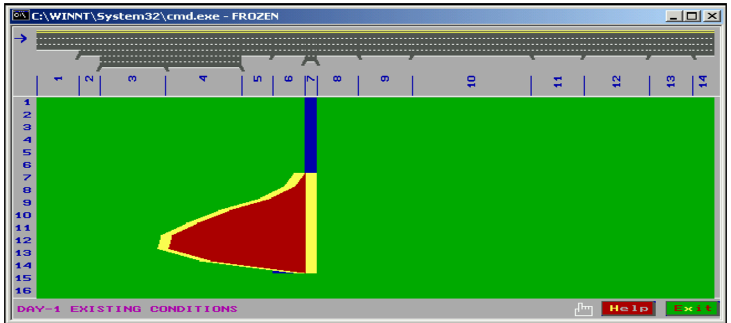
2010 SB 280 PM Peak

No Metering



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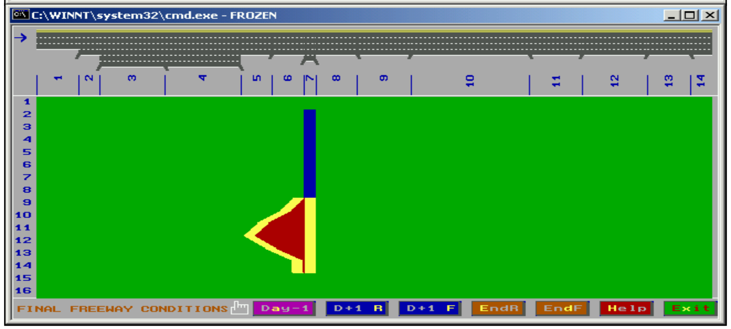

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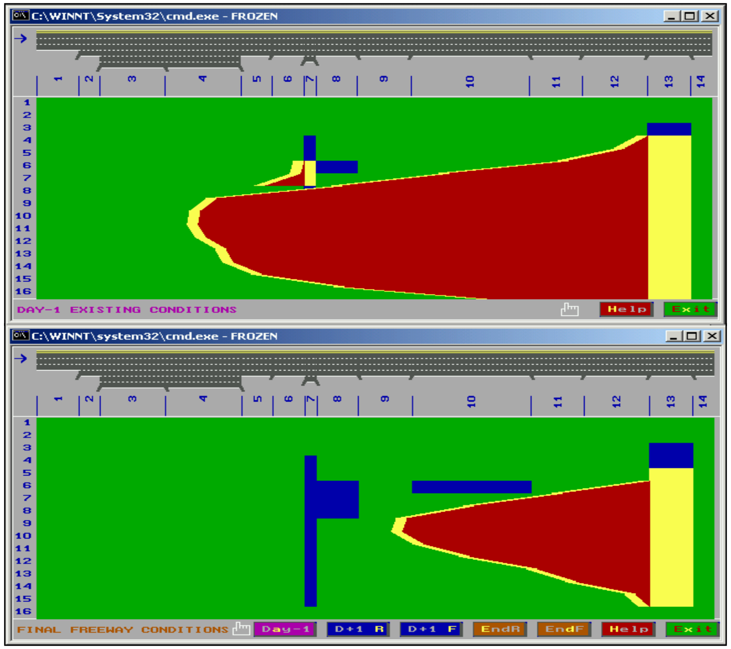
2020 SB 280 AM Peak

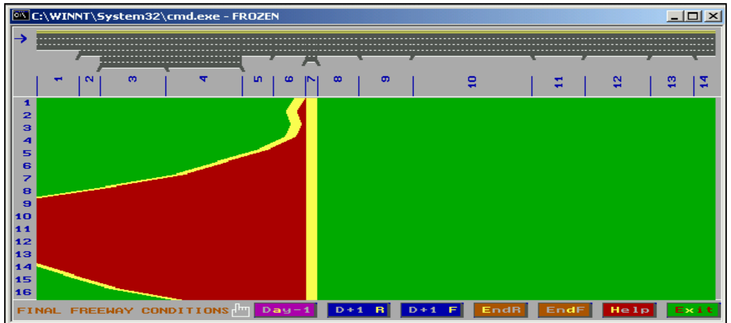
No Metering

Scenario 1

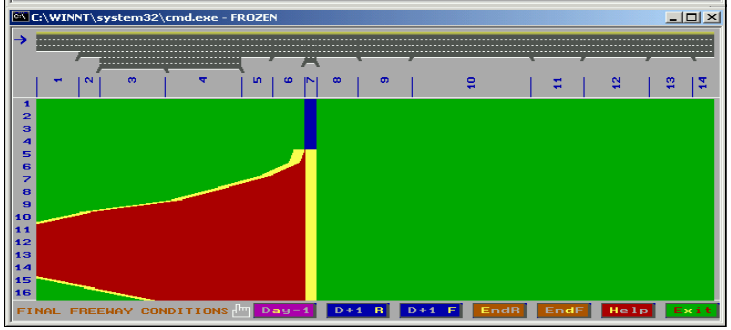


2020 SB 280 PM Peak

No Metering



Scenario 1



Scenario 2 Ramp Improvements (NB US 101)

- **Extended Queue Storage (doubled)**
  - Woodside (loop)
  - Whipple (loop)
  - Hillsdale (loop)
- **Widened for Throughput**
  - Woodside (loop) - 2020 PM only

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Scenario 2 Overflow Queues (50 Vehicles) - NB 101

- **Most other metered ramps on south end**
  - University -100 vehicles each (loop and diag)
  - Willow
  - Marsh
  - Woodside
  - Whipple
  - Holly
  - Ralston
  - Hillsdale - 100 vehicles on diag

Overall Scenario 2 Results - NB US 101

- **2010 PM not engaged**
- **Not able to reach 50% reduction in mainline delay**
- **Ramp + freeway delay varies widely, from -29% to +18%**

Year	Peak	Scenario	Mainline Delay (Veh-hrs)	% Δ in Mainline Delay	Ramp Delay (Veh-hrs)	Freeway + Ramp Delay	% Δ in Freeway + Ramp Delay	Mainline Speed
2010	AM	No Metering	2281		399	2680		56
		Metering 1 with diversion	1619	-29%	1147	2766	3%	60
		Metering 2 with diversion	1192	-48%	922	2114	-21%	62
2010	PM	No Metering	5220		693	5913		46
		Metering 1 with diversion	2061	-61%	2135	4196	-29%	58
		Metering 2 with diversion	n/a	n/a	n/a	n/a	n/a	n/a
2020	AM	No Metering	7581		3138	10719		40
		Metering 1 with diversion	7054	-7%	4068	11122	4%	41
		Metering 2 with diversion	6156	-19%	6467	12623	18%	43
2020	PM	No Metering	10514		523	11037		35
		Metering 1 with diversion	9920	-6%	565	10485	-5%	36
		Metering 2 with diversion	8158	-22%	3886	12044	9%	39

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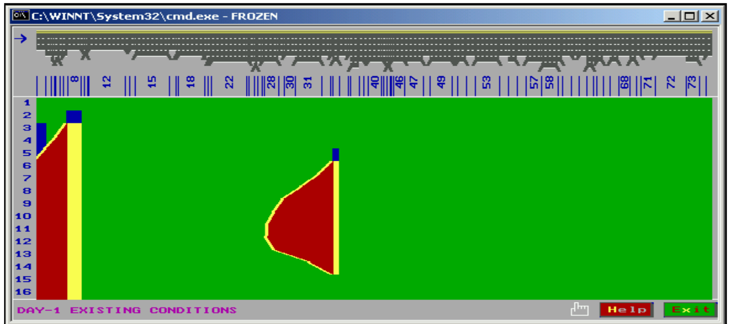
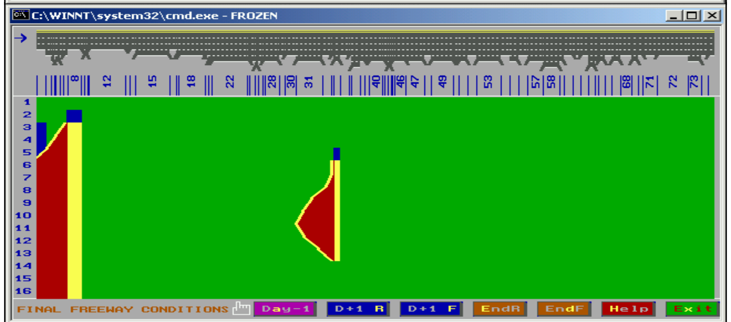
2010 NB US 101 AM Peak

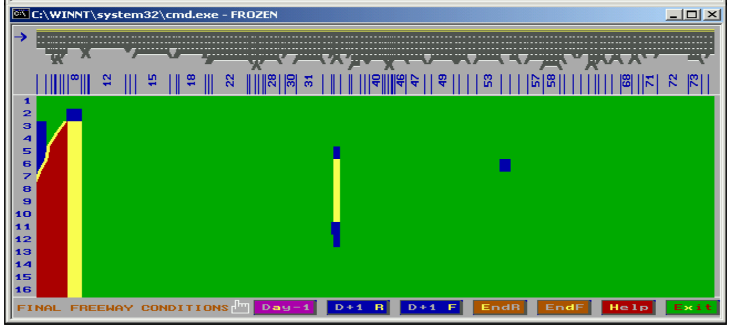
No Metering



Scenario 1



Scenario 2



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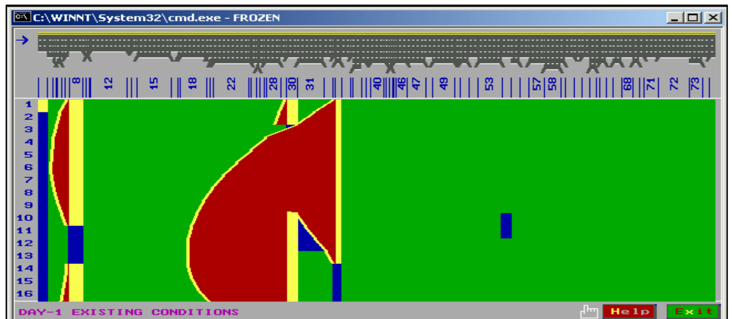
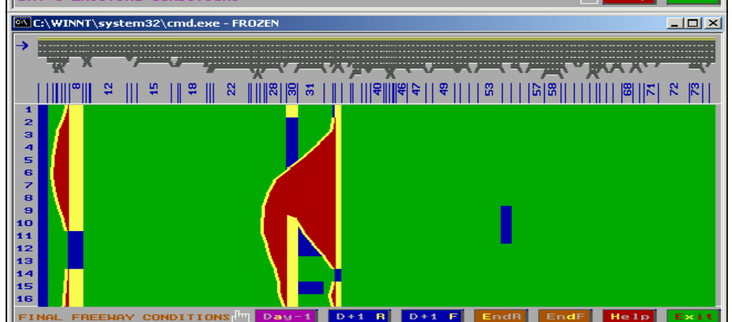
2010 NB US 101 PM Peak

No Metering



Scenario 1



Scenario 2

No need for action - Scenario 1 eliminates at least 50% of mainline delay

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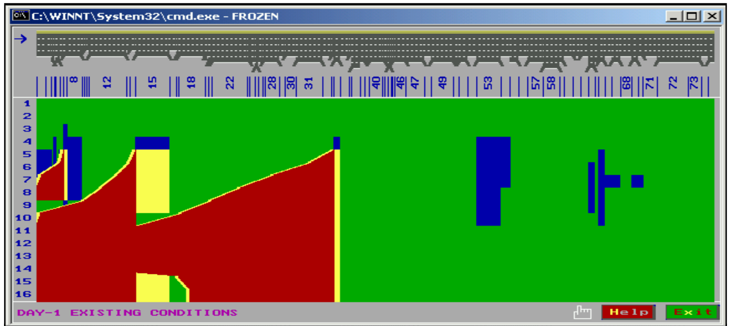
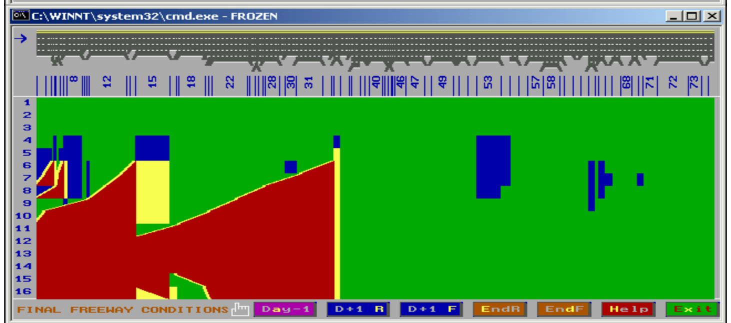
2020 NB US 101 AM Peak

No Metering



Scenario 1



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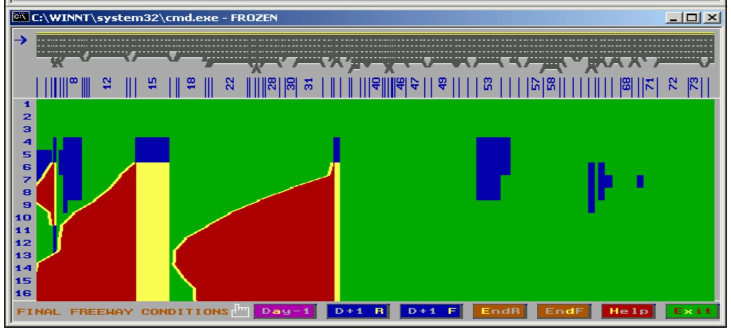

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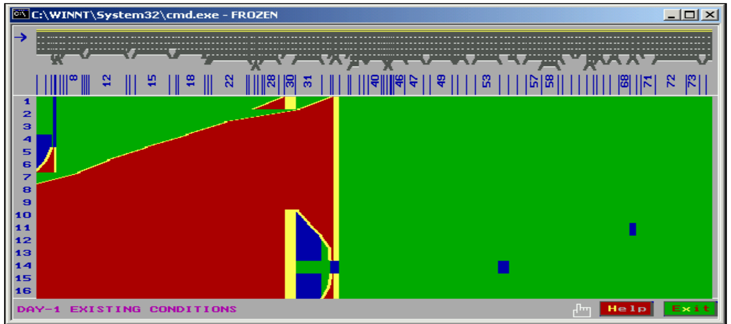
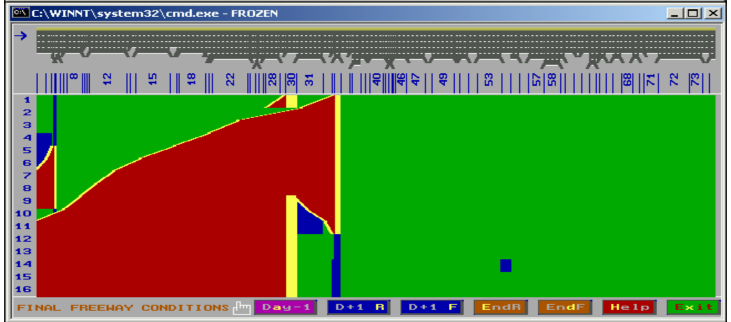
2020 NB US 101 PM Peak

No Metering



Scenario 1



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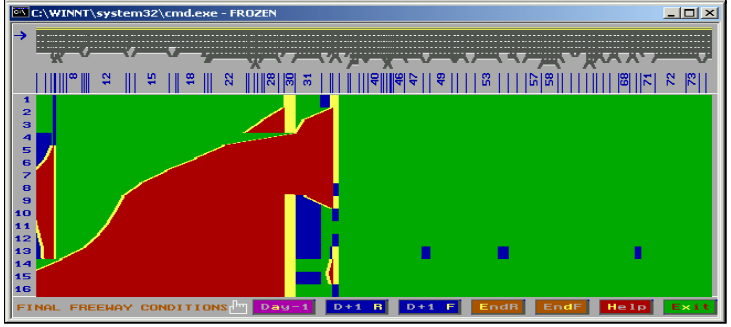

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Scenario 2 Ramp Improvements (SB US 101)

- **Extended Queue Storage (doubled)**
  - Harney
  - Sierra Point
  - Produce
  - Fashion Island
  - Woodside
  - Marsh (diagonal)
  - Willow (loop)
- **Widened for Throughput**
  - Hillsdale (loop)

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Scenario 2 Overflow Queues (50 Vehicles) - SB US 101

- **Most other metered ramps**
  - Bayshore
  - Oyster Point
  - San Bruno
  - Millbrae
  - Broadway
  - 3rd
  - Hillsdale (diagonal)
  - Holly
  - Brittan
  - Whipple
  - Marsh (loop)
  - Willow (diagonal)
  - University

Overall Scenario 2 Results - SB US 101

- **2020 PM not engaged**
- **Substantial reduction in mainline delay**
- **Moderate changes in overall ramp + freeway delay (some higher, some lower)**

Year	Peak	Scenario	Mainline Delay (Veh-hrs)	% Δ in Mainline Delay	Ramp Delay (Veh-hrs)	Freeway + Ramp Delay	% Δ in Freeway + Ramp Delay	Mainline Speed
2010	AM	No Metering	5818		66	5884		43
		Metering 1 with diversion	3550	-39%	1906	5456	-7%	51
		Metering 2 with diversion	2726	-53%	3270	5996	2%	54
2010	PM	No Metering	5964		1027	6991		41
		Metering 1 with diversion	5293	-11%	1875	7168	3%	43
		Metering 2 with diversion	2812	-53%	5079	7891	13%	53
2020	AM	No Metering	6993		499	7492		41
		Metering 1 with diversion	4868	-30%	1889	6757	-10%	47
		Metering 2 with diversion	2992	-57%	2335	5327	-29%	54
2020	PM	No Metering	627		10720	11347		65
		Metering 1 with diversion	253	-60%	15532	15785	39%	68
		Metering 2 with diversion	n/a	n/a	n/a	n/a	n/a	n/a

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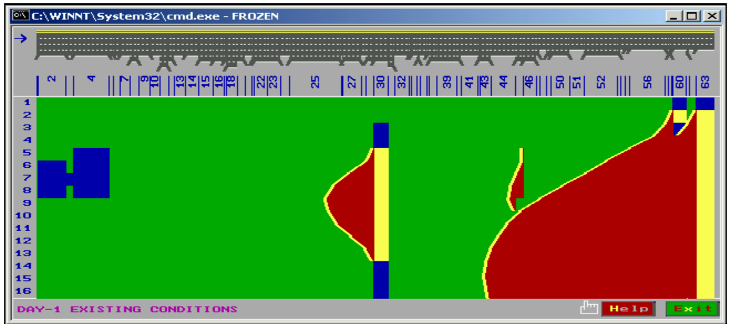
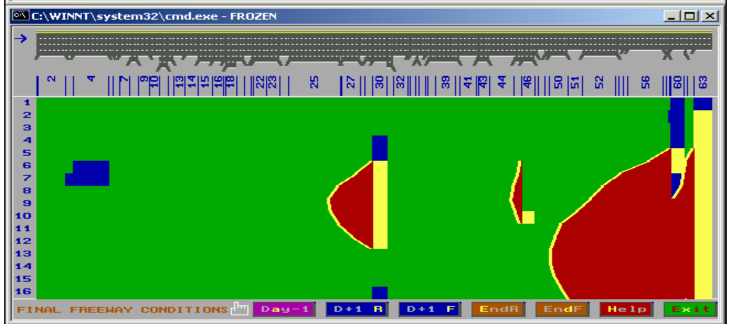
2010 SB US 101 AM Peak

No Metering



Scenario 1



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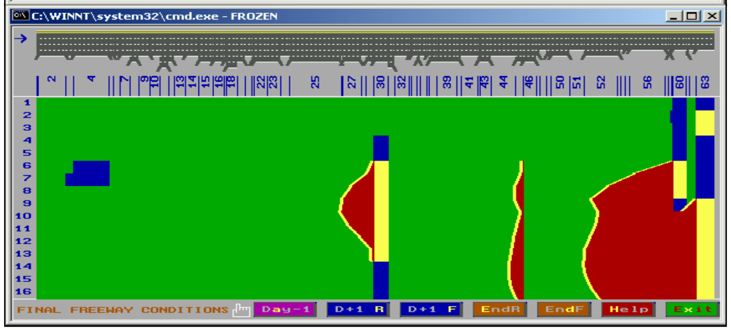

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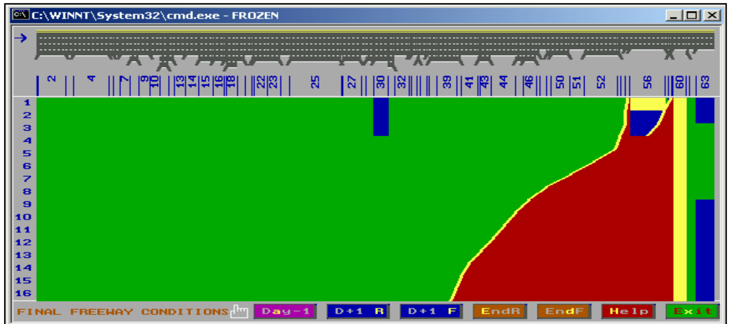
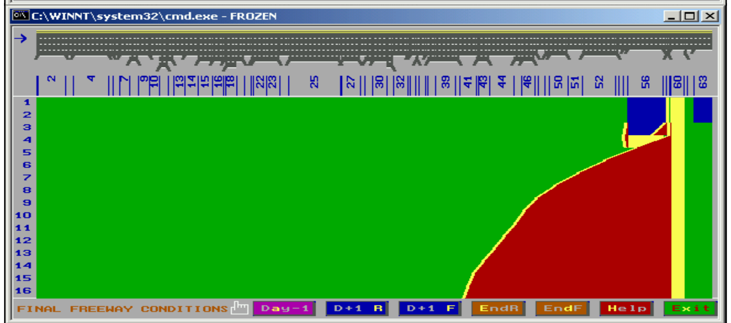
2010 SB US 101 PM Peak

No Metering



Scenario 1



Scenario 2

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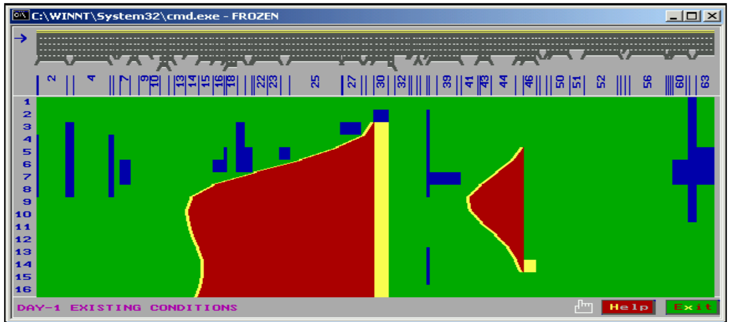
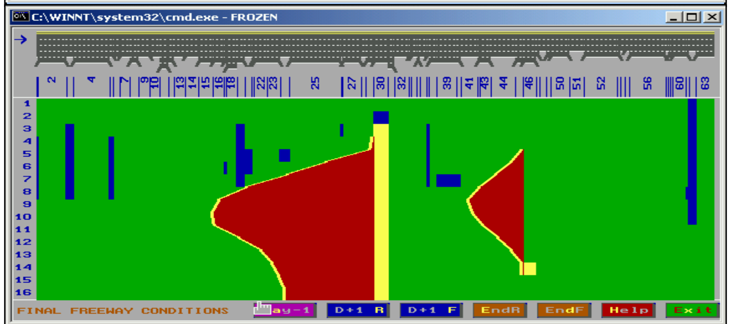
2020 SB US 101 AM Peak

No Metering



Scenario 1



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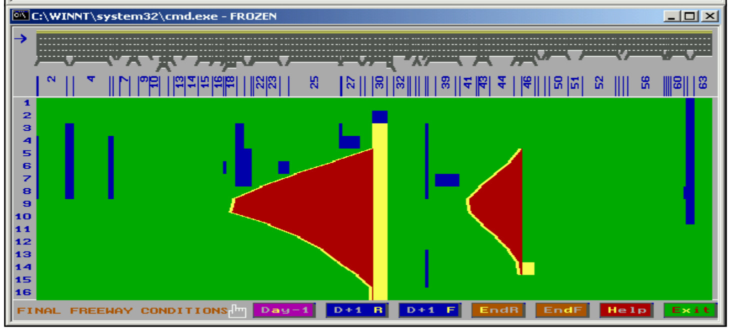

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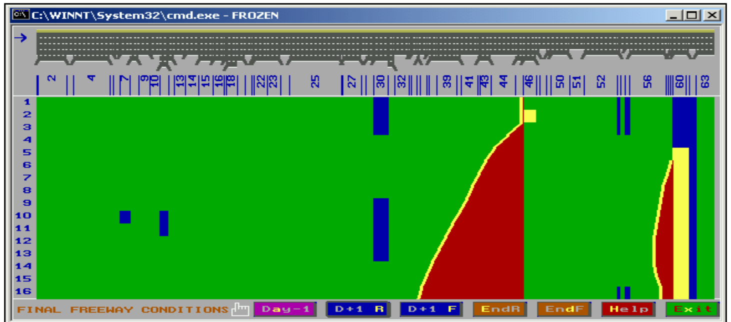
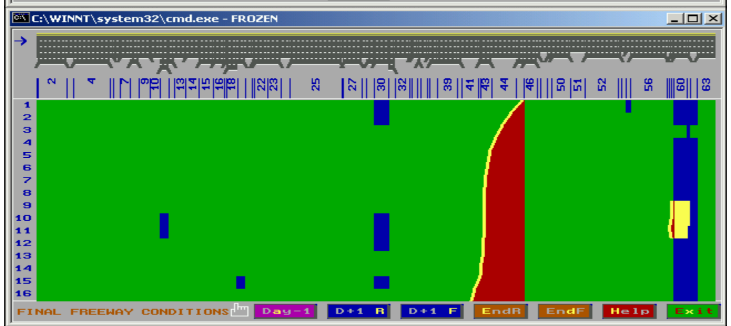
2020 SB US 101 PM Peak

No Metering



Scenario 1



Scenario 2

No need for action - Scenario 1 eliminates at least 50% of mainline delay

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Scenario 2 Improvements (280 NB)

- **Extended Queue Storage (doubled)**
  - Sneath
- **Overflow Queue of 15 vehicles**
  - Westborough Loop

Overall Scenario 2 Results - NB I-280

- Engaged for 2020 PM peak only

Year	Peak	Scenario	Mainline Delay (Veh-hrs)	% ∆ in Mainline Delay	Ramp Delay (Veh-hrs)	Freeway + Ramp Delay	% ∆ in Freeway + Ramp Delay	Mainline Speed
2010	AM	No Metering	51		0	51		68
		Metering 1 with diversion	51	0%	0	51	0%	68
		Metering 2 with diversion	n/a	n/a	n/a	n/a	n/a	n/a
2010	PM	No Metering	373		11	384		61
		Metering 1 with diversion	257	-31%	94	351	-9%	64
		Metering 2 with diversion	n/a	n/a	n/a	n/a	n/a	n/a
2020	AM	No Metering	341		0	341		60
		Metering 1 with diversion	96	-72%	5	101	-70%	67
		Metering 2 with diversion	n/a	n/a	n/a	n/a	n/a	n/a
2020	PM	No Metering	623		42	665		56
		Metering 1 with diversion	363	-42%	314	677	2%	61
		Metering 2 with diversion	304	-51%	457	761	14%	63

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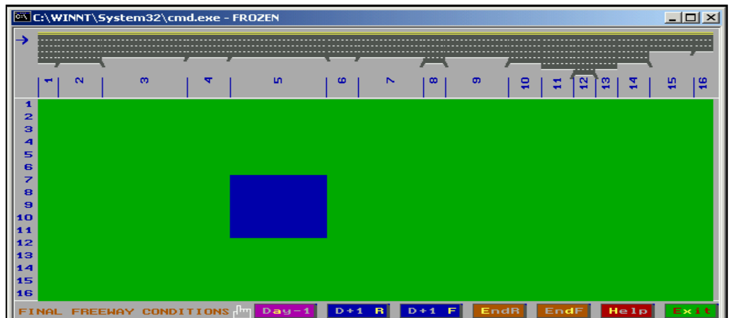
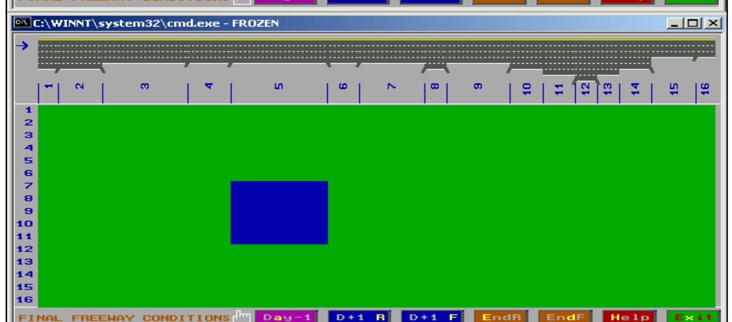
2010 NB 280 AM Peak

No Metering



Scenario 1



Scenario 2

No need for action - no delay

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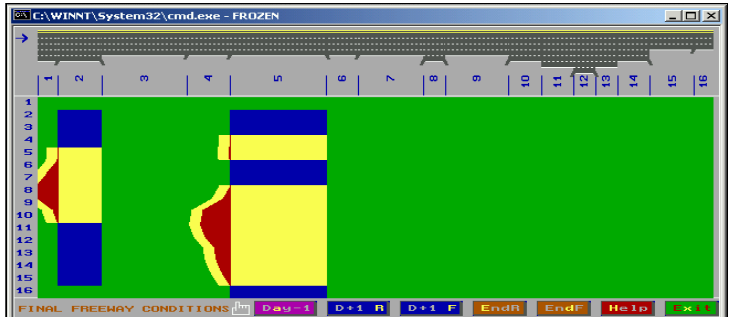
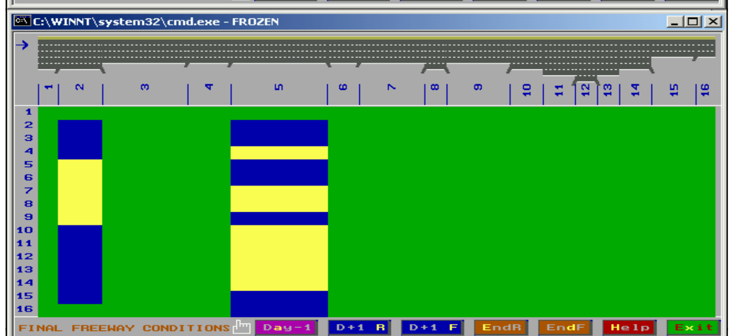
2010 NB 280 PM Peak

No Metering



Scenario 1



Scenario 2

No need for action - no delay

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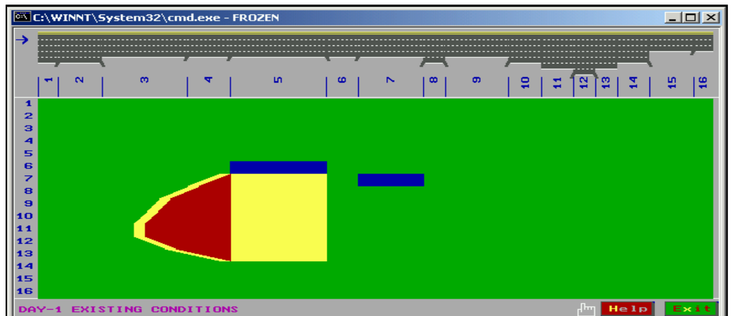
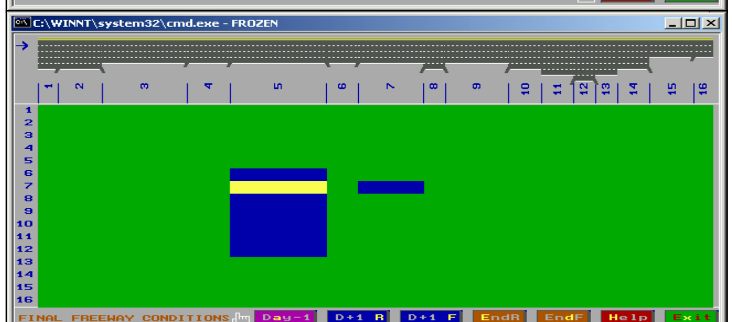
2020 NB 280 AM Peak

No Metering



Scenario 1



Scenario 2

No need for action - no delay

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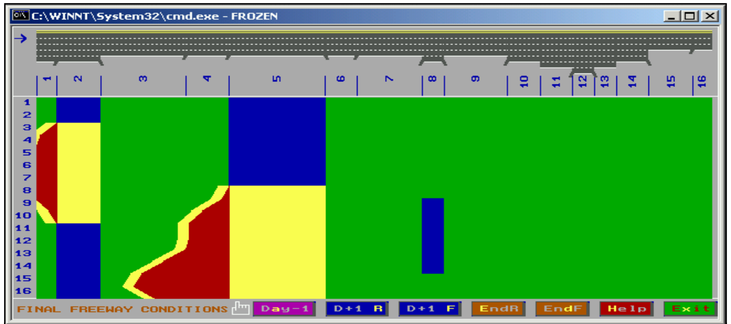
2020 NB 280 PM Peak

No Metering



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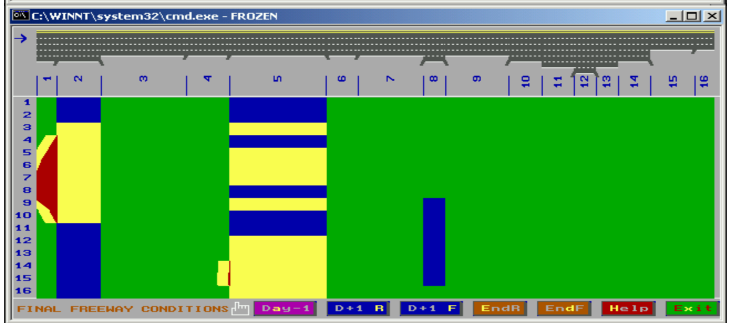

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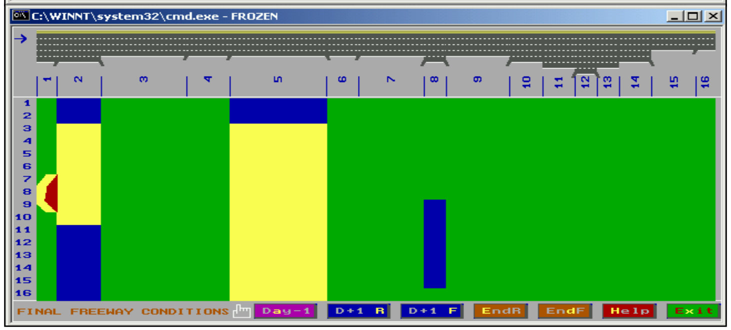

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Overall Scenario 2 Results - SB I-280

- **Not engaged for AM or PM peak**

Year	Peak	Scenario	Mainline Delay (Veh-hrs)	% Δ in Mainline Delay	Ramp Delay (Veh-hrs)	Freeway + Ramp Delay	% Δ in Freeway + Ramp Delay	Mainline Speed
2010	AM	No Metering	1091		0	1091		48
		Metering 1 with diversion	351	-68%	212	563	-48%	61
		Metering 2 with diversion	n/a	n/a	n/a	n/a	n/a	n/a
2010	PM	No Metering	561		6	567		56
		Metering 1 with diversion	163	-71%	119	282	-50%	65
		Metering 2 with diversion	n/a	n/a	n/a	n/a	n/a	n/a
2020	AM	No Metering	2448		1	2449		35
		Metering 1 with diversion	903	-63%	350	1253	-49%	51
		Metering 2 with diversion	n/a	n/a	n/a	n/a	n/a	n/a
2020	PM	No Metering	2249		594	2843		36
		Metering 1 with diversion	1888	-16%	707	2595	-9%	39
		Metering 2 with diversion	n/a	n/a	n/a	n/a	n/a	n/a

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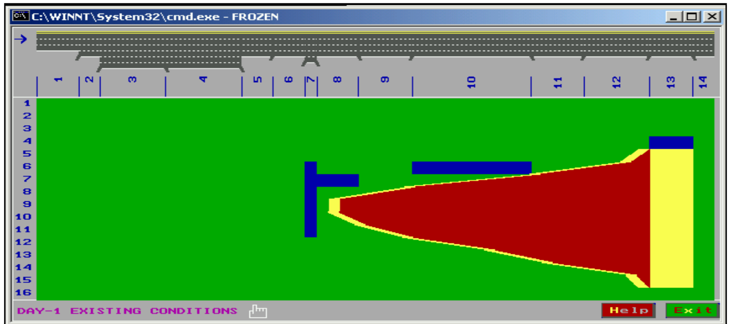
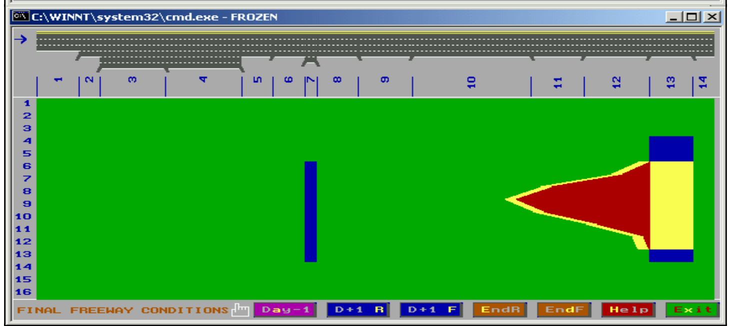
2010 SB 280 AM Peak

No Metering



Scenario 1



Scenario 2

No need for action - Scenario 1 eliminates at least 50% of mainline delay

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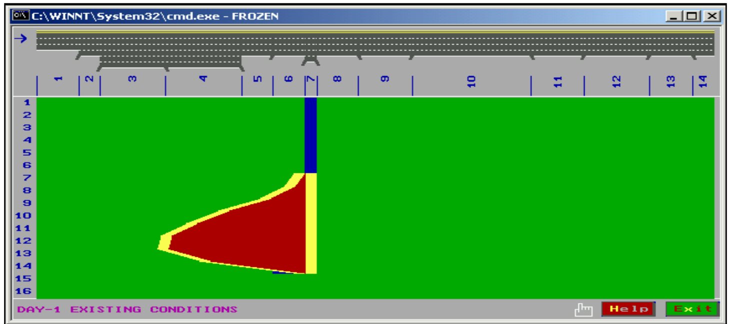
2010 SB 280 PM Peak

No Metering



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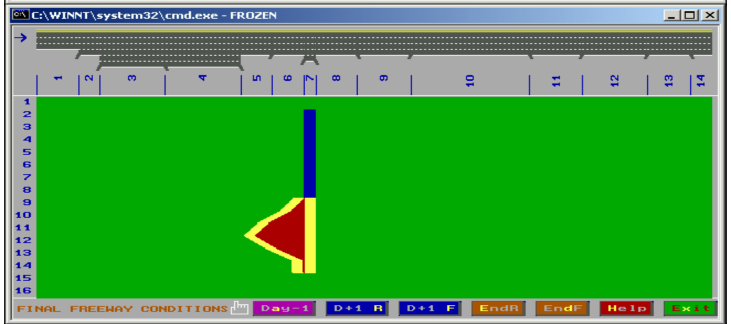

Scenario 2

No need for action - Scenario 1 eliminates at least 50% of mainline delay

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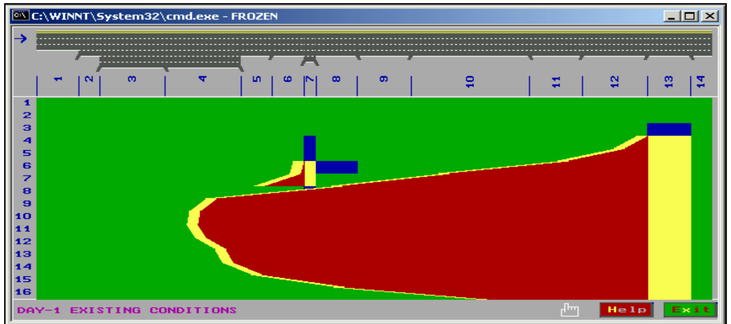
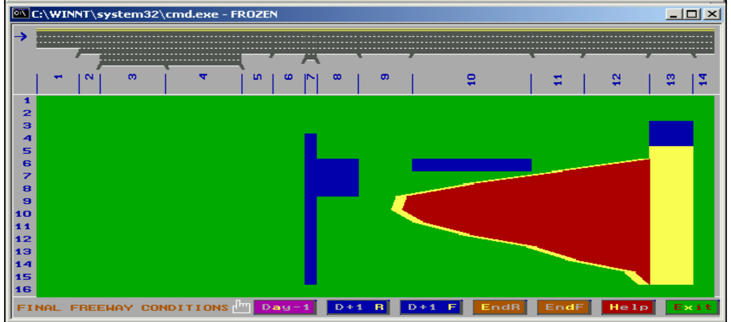
2020 SB 280 AM Peak

No Metering



Scenario 1



Scenario 2

No need for action - Scenario 1 eliminates at least 50% of mainline delay

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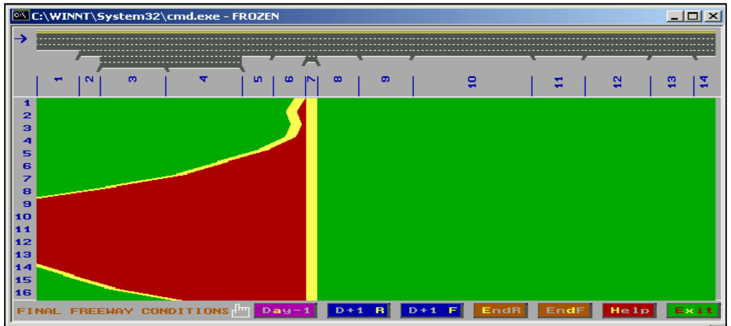
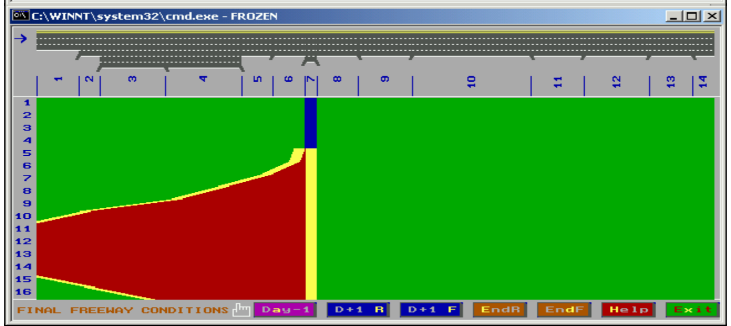
2020 SB 280 PM Peak

No Metering



Scenario 1



Scenario 2

No action can be taken - ramp demands too high

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Summary of Mainline and Ramp Impacts (Delay)

	Metering Scenario 1		Metering Scenario 2	
	Mainline	Mainline + Ramps	Mainline	Mainline + Ramps
2010AM I-280 NB	0%	0%	n/a	n/a
2010PM I-280 NB	-31%	-9%	n/a	n/a
2020AM I-280 NB	-72%	-70%	n/a	n/a
2020PM I-280 NB	-42%	2%	-51%	14%
2010AM I-280 SB	-68%	-48%	n/a	n/a
2010PM I-280 SB	-71%	-50%	n/a	n/a
2020AM I-280 SB	-63%	-49%	n/a	n/a
2020PM I-280 SB	-16%	-9%	n/a	n/a
2010AM US101 NB	-29%	3%	-48%	-21%
2010PM US101 NB	-61%	-29%	n/a	n/a
2020AM US101 NB	-7%	4%	-19%	18%
2020PM US101 NB	-6%	-5%	-22%	9%
2010AM US101 SB	-39%	-7%	-53%	2%
2010PM US101 SB	-11%	3%	-53%	13%
2020AM US101 SB	-30%	-10%	-57%	-29%
2020PM US101 SB	-60%	39%	n/a	n/a
Average	**-38%**	**-15%**	**-43%**	**1%**
Maximum	**0%**	**39%**	**-19%**	**18%**
Minimum	**-72%**	**-70%**	**-57%**	**-29%**

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Origin-Destination Travel Time

- **Measured for AM & PM peak-hour**
- **Travel time includes mainline delay and origin on-ramp metering delay**
- **OD pairs selected based on corridor congestion and logical termini**

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101 NB Travel Time Between X and Y

- Pair 1: Corridor - mainline south of University to mainline north of Harney (26.6 mi)
- Pair 2: Willow Loop on to Holly CD off (6.5 mi)
- Pair 3: Marsh Loop on to SFO off (15.2 mi)
- Pair 4: 3rd Loop on to Oyster off (9.1mi)

			Pair 1	Ramp	Pair 2	Ramp	Pair 3	Ramp	Pair 4	Ramp
Year	Peak	Scenario	TT (min)	Delay	TT (min)	Delay	TT (min)	Delay	TT (min)	Delay
2010	AM	No Metering	29		6		15		8	
		Metering 1 with diversion	**28**	1	**7**	1	15	1	8	0
		Metering 2 with diversion	**27**	0	6	0	**14**	0	8	0
2010	PM	No Metering	31		6		19		8	
		Metering 1 with diversion	**30**	1	6	0	19	2	8	0
		Metering 2 with diversion	n/a	-	n/a	-	n/a	-	n/a	-
2020	AM	No Metering	36		9		22		8	
		Metering 1 with diversion	**33**	0	**10**	2	**21**	2	8	0
		Metering 2 with diversion	**30**	0	**10**	3	**23**	5	**9**	0
2020	PM	No Metering	53		26		32		8	
		Metering 1 with diversion	53	0	26	0	**34**	2	8	0
		Metering 2 with diversion	**46**	0	**25**	3	**39**	7	8	0

101 SB Travel Time Between X and Y

- Pair 1: Corridor - mainline north of Harney to south of University (26.7 mi)
- Pair 2: Holly on to Willow off (5.9 mi)
- Pair 3: SFO on to Marsh off (15.6 mi)
- Pair 4: Oyster on to 3rd off (9.1 mi)

Year	Peak	Scenario	Pair 1 TT (min)	Ramp Delay	Pair 2 TT (min)	Ramp Delay	Pair 3 TT (min)	Ramp Delay	Pair 4 TT (min)	Ramp Delay
2010	AM	No Metering	34		11		17		9	
		Metering 1 with diversion	32	0	10	0	17	0	9	0
		Metering 2 with diversion	30	0	10	1	16	0	8	0
2010	PM	No Metering	51		31		34		8	
		Metering 1 with diversion	49	0	31	1	31	0	12	4
		Metering 2 with diversion	36	0	19	1	18	0	15	7
2020	AM	No Metering	37		5		27		19	
		Metering 1 with diversion	36	0	5	0	25	0	18	0
		Metering 2 with diversion	34	0	5	0	24	0	15	0
2020	PM	No Metering	26		6		14		8	
		Metering 1 with diversion	24	0	11	6	14	0	8	0
		Metering 2 with diversion	n/a	-	n/a	-	n/a	-	n/a	-

280 NB Travel Time Between X and Y

- Pair 1: Corridor - mainline south of Sneath to mainline north of Knowles (6.3 mi)
- Pair 2: Sneath on to John Daly off (5.0 mi)

Year	Peak	Scenario	Pair 1 TT (min)	Ramp Delay	Pair 2 TT (min)	Ramp Delay
2010	AM	No Metering	6		5	
		Metering 1 with diversion	6	0	5	0
		Metering 2 with diversion	n/a	-	n/a	-
2010	PM	No Metering	7		5	
		Metering 1 with diversion	6	0	5	0
		Metering 2 with diversion	n/a	-	n/a	-
2020	AM	No Metering	6		5	
		Metering 1 with diversion	6	0	5	0
		Metering 2 with diversion	n/a	-	n/a	-
2020	PM	No Metering	7		5	
		Metering 1 with diversion	6	0	7	2
		Metering 2 with diversion	6	0	8	3

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280 SB Travel Time Between X and Y

- Pair 1: Corridor - mainline north of John Daly to mainline south of Sneath (6.3 mi)
- Pair 2: John Daly on to Sneath off (5.7 mi)

			Pair 1	Ramp	Pair 2	Ramp
Year	Peak	Scenario	TT (min)	Delay	TT (min)	Delay
2010	AM	No Metering	7		7	
		Metering 1 with diversion	7	0	6	0
		Metering 2 with diversion	n/a	-	n/a	-
2010	PM	No Metering	9		8	
		Metering 1 with diversion	6	0	6	0
		Metering 2 with diversion	n/a	-	n/a	-
2020	AM	No Metering	9		8	
		Metering 1 with diversion	8	0	7	0
		Metering 2 with diversion	n/a	-	n/a	-
2020	PM	No Metering	17		14	
		Metering 1 with diversion	16	1	14	0
		Metering 2 with diversion	n/a	-	n/a	-

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Average Ramp Delay Due to Ramp Metering

Year	Peak	Scenario	101 NB	101 SB	280 NB	280 SB
2010	AM	1	3	4	0	4
		2	5	7	n/a	n/a
2010	PM	1	4	4	2	7
		2	n/a	9	n/a	n/a
2020	AM	1	3	3	0	5
		2	10	3	n/a	n/a
2020	PM	1	3	6	4	9
		2	10	n/a	6	n/a

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Maximum Ramp Delay Due to Ramp Metering

Year	Peak	Scenario	101 NB	101 SB	280 NB	280 SB
2010	AM	1	10	13	0	27
		2	23	24	n/a	n/a
2010	PM	1	26	11	8	28
		2	n/a	31	n/a	n/a
2020	AM	1	12	12	1	28
		2	27	15	n/a	n/a
2020	PM	1	3	52	16	31
		2	39	n/a	17	n/a

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Next Steps

- Diversion Analysis

Appendix H – Diversion and Local Street Analysis Results

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MEMORANDUM

TO: Peninsula Avenue Ramp Metering Study – Working Group

FROM: Terry Klim

DATE: July 23, 2004

SUBJECT: Technical Memorandum #7/8 – Diversion and Local Street Analysis

P/A No. 03018-000x008
03018-000x009

INTRODUCTION

This technical memorandum is a combined deliverable for Task 8 ("Diversion Analysis") and Task 9 ("Local Street Analysis) of the Peninsula Avenue Corridor Ramp Metering Study. The objective of this study is to identify the potential impacts of ramp metering within the Peninsula Avenue Corridor. The study area includes US Highway 101 (US 101) within San Mateo County, and the northern section of and Interstate 280 (I-280), from I-380 to the San Francisco County line. This study includes two forecast years: 2010 and 2020.

The first part of the project focused on the freeway operational impacts of ramp metering. The goal of this series of steps was to determine if ramp metering can provide any significant operational benefits to the freeways in the study area. The analysis conducted in this part of the project did show that ramp metering could provide operational benefits to the freeway for certain segments and time periods. The results from this analysis are presented in Tech Memo #6. The second part of this study examines the potential diversion or re-routing of trips due to the delay at the ramp meters and is the focus of this technical memorandum.

This memorandum summarizes the forecasted. The following section describes the methodology used for this part of the analysis, including how the EMME/2 travel demand modeling software was used to forecast potential diversion and the approach used for evaluating the potential impacts. The results of this analysis are presented in the third section of this memo. Summary conclusions derived from this analysis are presented in the final section.

METHODOLOGY

Diversion Modeling

In Task 7, the freeway operational effects of ramp metering were analyzed using the FREQ simulation modeling software. Separate FREQ models were developed for the 4-hour AM and PM peak periods for both 2010 and 2020. The FREQ model provides the typical ramp delay for each 15-minute interval within the peak period.

To analyze the potential diversion that may result from ramp metering, the meter delay outputs from FREQ were incorporated into the C/CAG countywide travel demand model. This was done by converting the meter delays generated by FREQ into fixed time penalties on the ramp links within the travel demand model. Because the travel model is also a peak period forecast, as opposed to a peak hour, the average meter delay from all 15-minute intervals from FREQ were used.

It is important to note that for this analysis it was assumed that meters would be installed on all on-ramps within the study area. However, depending on various factors such as the level of forecasted demand at a potential ramp and mainline conditions, the level of metering can vary. For ramps showing no delay during a particular period, this generally means that the meters are set at a rate that results in little or no delay to vehicles during that time period.

The average meter delays (rounded to the nearest minute) at each ramp for the AM and PM peak periods in both horizon years are presented in Appendix A. Figures 1 through 4 illustrate which ramps have meter delays under each forecast period. For the purpose of this study, ramps with meter delay during a particular period are referred to as having “active metering” for that period.

Levels of Assessment

To provide a comprehensive picture of potential impacts, an assessment was conducted at both the regional and localized levels. In general, the regional assessment looked at changes in forecasted demand for major links and screenlines. At the localized level, the assessment focused on the impacts to individual ramps and intersections. Table 1 summarizes the different components included in the assessment. Each component is further discussed below.

Table 1
Evaluation Components

Component	Description
Regional	
Freeway Mainline	Examines changes in forecasted demand for individual freeway links.
Screenlines	A set of screenlines cutting across the study freeways and parallel arterial facilities were defined within the study corridor. Examines change in forecasted demand between freeway and arterial facilities at each screenline.
On-Ramps	Aggregate change to forecasted demand.
Local	
On-Ramps	Change in forecasted demand for individual ramps.
Intersection	Change in forecasted LOS for individual intersections.
Ramp Queue Spillback	Locations where queues from ramp meters may extend back to local streets and impact local street operations.

Freeway Mainline

This component simply looks at changes in the forecasted demand on the freeway. This comparison provides insights into potential shifts in overall freeway travel.

Screenlines

For this component, a set of screenlines cutting across the study freeways and major parallel arterials were identified within the corridor. For each screenline, the forecasted demands without and with metering were compared with an emphasis on the distribution of this demand between the freeway and the parallel arterials.

The assessment of screenlines is useful in identifying shifts in travel between the freeways and parallel arterials and identifying those facilities most significantly impacted. The screenlines included in this analysis are illustrated in Figure 5. The selected screenlines are located throughout the county and capture travel through most cities in the study area. A listing of the specific roadway facilities included in each screenline is provided in Appendix B.

On-Ramps

As with the freeway and screenlines components, this component examined the forecasted change in demand as generated by the travel demand model. Taken in aggregate, this is useful for highlighting changes in overall demand on the freeway (i.e. if total volume entering the freeway increases or decreases). Individually, the comparison of the forecasted demand at on-ramps is useful for highlighting shifts between on-ramps. This comparison includes all on-ramps in the study area.

Intersection LOS

A primary concern for local agencies is how any shift in travel demand may impact local street operations. To address this concern, the level of service (LOS) without and with metering was calculated for various signalized intersections. A key to this component was in identifying which intersections to analyze for each period with a goal of managing the level of effort required and focusing those locations most impacted.

The process of identifying the analysis locations began with defining a set of candidate signalized intersections. The locations included in the list were selected based on their proximity to a freeway interchange, and how “realistically” they were modeled within the travel demand model. In some cases, intersections were not included in the candidate list because they were either not included in the model network or not accurately modeled. The candidate intersections are illustrated in Figure 6 and listed in Appendix C.

The second step in the process was to identify those candidate locations most impacted with the implementation of metering and screening out those forecasted to have little or no impact. This was done by looking at the change in the forecasted intersection turn movement volumes and relating any changes to the proposed ramp metering. The specific criteria used for this screening process included:

- total peak period (3-hour) intersection volumes increased by 1000 or more, or
- total peak period (3-hour) demand any individual approach increased by 500 or more; and
- intersection is located within reasonable proximity to ramps with active metering.

For each scenario, LOS analysis was conducted only for those intersections meeting the above criteria.

Ramp Queue Spillback

A second concern of local agencies was whether queues from ramp meters would extend back and impact local street operations. This might occur if queues extended onto local streets blocking through lanes or intersections. This assessment was conducted using the queue length outputs from FREQ and comparing them to the estimated storage capacities of each ramp.

ANALYSIS RESULTS

The analysis results for each of the components described above are presented in following sections. In each case, general observations about the results are provided and significant changes are highlighted.

In general, it was observed that the addition of ramp meter delays resulted in some significant, and sometimes non-intuitive, shifts in travel demand. While higher-volume facilities such as the freeways remained rather stable, significant shifts were observed on links far removed from the study freeways and the associated ramp metering. In a few cases, links leading to an actively metered ramp experienced an increase in forecasted demand. A direct correlation between these results and the location and magnitude of ramp metering is difficult to establish.

Such results illustrate the volatility of the travel demand model. This may be due, in part, to the high level of saturation within the model. By 2020, most major facilities, including most study freeway segments, are forecast to operate with volume-to-capacity ratios well above 1.0. The overall level of congestion in the corridor and the latent demand for vehicles entering the corridor may be impacting the results. As part of this analysis, professional judgment was used to reconcile the forecasted changes produced by the model with what would be logically expected.

Freeway Mainline

Forecasted travel demands for a number of freeway links are included with the screenline results in Tables 2 and 3 for 2010 and 2020 respectively.

The model results show that US 101 will experience only modest changes with the ramp metering. In most instances the forecasted volumes along US 101 with metering are within 2 or 3 percent of those without metering. The exception occurs just south of SR 92 where forecasted volumes are up to 9% lower in 2010. This is likely the result of ramp meter delays at the Hillsdale on-ramps leading to shifting of trips to adjacent ramps.

The volumes on I 280 north of I-380 generally decrease an average of two percent (around 500 vehicles in the peak hour) with the ramp metering. These changes are not considered significant.

As noted above, many of the freeway links along both freeways and in both horizon years experience volume-to-capacity ratios greater than one.

Screenlines

The screenline assessment results are summarized in Tables 2 and 3 for 2010 and 2020 respectively.

As illustrated in these tables, most screenlines have negligible changes in volumes, less then two percent. The following highlights the screenlines with the greatest shifts as a result of the ramp metering analyzed:

- South of Harney/ County Line – In the PM peak period of 2020 horizon year, this screenline is forecasted to have a three percent decrease in both the northbound and southbound directions.
- South of Millbrae Ave - In the PM peak period of 2020 horizon year, this screenline is forecasted to have a three percent decrease in the northbound direction.
- South of Hwy 92 – In the PM peak period of 2010 horizon year, this screenline is forecasted to have a three percent decrease in the southbound direction and a four percent decrease in the northbound direction.

More importantly, the relative distribution of traffic between the freeways and parallel arterials (as measured by the % of total screenline traffic on the freeways versus on the arterials) does not change for most screenlines. For those that do change, they are fairly evenly split between those where the freeway share increases and those where the arterial share increases. Even then, the change is only 1%, except for during the 2010 PM where there is a 2% shift in traffic demand to the arterials for the screenline south of SR 92. These results are further evidence that ramp metering is not expected to result in the diversion of trips to arterial roadways.

Ramps

The diversion analysis results for on-ramps are presented in Tables 4 and 5 for 2010 and 2020 respectively.

In total, on-ramp volumes to northbound 101 are forecasted to decrease approximately 10% in each period. Southbound, the forecasted decrease varies between 3% and 26% depending on period. These decreases combined with the fact that freeway mainline demands do not change significantly suggests that with metering those using the on-ramps are staying on the freeway longer (thus maintaining freeway volumes) and that the decrease in ramp volumes is a result of fewer short on-off trips. This result is expected because longer trips capture more benefit from the improved freeway operation and can compensate for any delay at the ramp meter.

On I-280, on-ramp demands remain relatively constant for most periods. The primary exception occurs in the 2020 PM where on-ramp demands decrease 7% in the southbound direction, 10% for the northbound direction.

With respect to individual ramps, those subject to meter delays for a particular period are generally forecasted to experience a reduction in demand volumes. However, the magnitude of this change varies greatly and is a function of several factors including the magnitude of the meter delay at that ramp, the availability of alternative routes, and the magnitude of meter delay at adjacent ramps. In a limited number of cases, ramps with low meter delays experience increases in demand volumes. This occurs when adjacent ramps are subject to relatively higher meter delays.

The trend for ramps with no metering delays is less obvious. For example, while some ramps with no metering delay that are adjacent to ramps with a meter delay do experience an increase in forecasted demand as expected, others are forecast to have decreased demands.

Likewise, ramps with no meter delay that are not adjacent to ramps subject to a meter delay also experience variability in the changes in demand volumes. This variability may be due to high levels of congestion along the freeways. Many of the freeway links in both horizon years experience volume-to-capacity ratios greater than one.

The following highlights several of the changes at the ramps as a result of the analyzed ramp metering:

- For northbound US 101, ramps in the northern section of the corridor experience some significant changes in demand volumes with metering despite the fact that none of these ramps are subject to meter delays. For example, Peninsula Avenue has a 55 percent decrease in the 2010 AM and a 28 percent increase in the 2010 PM.
- In the 2010 AM peak, several ramps along southbound US 101 experience significant reductions in demand volumes as a result of metering. These include the Woodside loop, Holly loop, Marine/Ralston diagonal, Hillsdale loop and Hillsdale diagonal ramps.
- In the 2010 horizon year, the southbound US 101 Millbrae Avenue Loop is forecast to have a significant increase in demand volume (264 percent increase in volume in the AM peak period and a 32 percent increase in volume in the PM peak period) despite metering and having delays.
- In the 2020 horizon year, the southbound US 101 Hillsdale Avenue Loop with metering has a decrease of 92 percent in the AM peak period and a 65 percent decrease in the PM peak period.

- The southbound I-280 Sullivan Avenue ramp, which is metered, has a decrease in volumes in both horizon years in the AM and PM peak periods.

Intersection LOS

As described earlier LOS analysis was conducted only for those intersections that met a specific set of criteria. This number varied by scenario. Interestingly, the number of intersections meeting the criteria was lower for 2020. This may be because the network is more congested and therefore alternative routes are less available or attractive.

2010 AM

Of the 75 candidate intersections, 6 intersections were identified as having significant changes in travel demand as a result of ramp metering and met the criteria for further analysis. The without and with metering LOS results for these intersections are shown in Table 6.

As shown in this table, 3 of these 6 intersections are forecast to experience a notable degradation in level-of-service (defined as a 5 second or greater increase in average vehicle delay). These locations are:

- #31 – Ralston/el Camino Real
- #33 – Twin Dolphin/redwood Shores
- #124 – Harbor/Industrial

One intersection (Hillsdale/Edgewater) is forecast to a have slight reduction in delay, the other two are forecast to operate at LOS F with delay exceeding 100 seconds under both the without and with metering scenarios.

2010 PM

For this period, 11 intersections are forecast to experience significant changes in travel demand as a result of ramp metering and meet the criteria for further analysis. The without and with metering LOS results for these intersections are shown in Table 7.

In this case, only 1 intersection (Grand/Gateway) is forecast to experience a notable degradation in level-of-service, while 7 intersections are forecast to a have reduction in delay. The remaining 3 intersections are forecast to operate at LOS F with delay exceeding 100 seconds under both the without and with metering scenarios.

2020 AM

Seven of the candidate intersections are forecasted to have significant changes in travel demand as a result of ramp metering and meet the criteria for further analysis. The without and with metering LOS results for these intersections are shown in Table 8.

For this period, none of the intersections are forecast to experience a notable degradation in level-of-service. Indeed, 3 intersections are forecast to a have reduction in delay, with the other 3 forecast to operate at LOS F with delay exceeding 100 seconds under both the without and with metering scenarios.

2020 PM

Only 4 of the candidate intersections are forecasted to have significant changes in travel demand as a result of ramp metering and meet the criteria for further analysis. The without and with metering LOS results for these intersections are shown in Table 9.

For this period, one intersection (San Bruno/NB 101 ramps) is forecast to experience a notable degradation in level-of-service. Of the remaining 3 locations, one is forecast to a have reduction in delay, and 2 are forecast to operate at LOS F with delay exceeding 100 seconds under both the without and with metering scenarios.

Ramp Queue Spillback

By definition, queues onto local streets were not permitted for the metering scenario analyzed. While exact length of queue varied by ramp, the guiding principal was that meter queues would be limited to the storage available on the ramp plus any dedicated lane on surface streets.

In the field this would be achieved by installing "spillback" detectors at the point of the acceptable queue limit. When of this length or beyond one detector, the meter can be programmed to increase the metering rate (or even go "all green") for a period of time to shorten or dissipate the queue then return to normal operation.

CONCLUSIONS

There was a great deal of variability found in the diversion analysis of the ramp metering scenario. Numerous individual ramp and arterials links are forecast to experience significant changes in demand. In many cases a direct correlation between these results and the location and magnitude of ramp metering is difficult to establish. The overall level of congestion in the corridor and the latent demand for vehicles entering the corridor may be impacting the results.

From a regional perspective, ramp metering is not expected to result in a significant shift in demand to or from the freeway. In general, freeway mainline volumes and the split of demand between the freeway and parallel arterials remain fairly constant without and with metering. However, total on-ramp volumes to US 101 are forecasted to decrease between 5 and 19% depending on the period and direction. These decreases combined with the fact that freeway mainline demands do not change significantly suggests that with metering those using the on-ramps are staying on the freeway longer (thus maintaining freeway volumes) and that the decrease in ramp volumes is a result of fewer short on-off trips. This result is expected because longer trips capture more benefit from the improved freeway operation and can compensate for any delay at the ramp meter.

With respect to individual ramps, forecasts do show a shifting of demand from higher-delay ramps to those with lesser or no delay, as would be expected. In reality, this shift in demand would also result in changes to the metering rates and delays at the affected ramps causing a possible shifting back and forth of trips until equilibrium is achieved. As evidenced by the relatively stable freeway mainline and screenline results, these shifts are largely very localized with trips shifting between adjacent ramps not diverting entirely from the freeway.

A more detailed examination of local facilities does reveal that a number of intersections in each time period are forecast to experience a significant increase or re-distribution of trips. In some cases these changes do not significantly degrade service levels. This may occur where the increase or re-distribution of demand results in a balancing of traffic flows within the intersection. However, in each period a small number of intersections are forecast to experience notable increases in delay. Mitigation measures for these locations would be appropriate.

By definition, local street operations would not be impacted by the spillback of queues from the ramp meters. The metering scenario analyzed includes the provision that queues be limited to the storage available on the ramp plus any dedicated lane on surface streets.

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Table 2
2010 Screenline Peak Hour Volume Changes

	Forecasted Demand Volumes (Peak Hour[1])							
	AM				PM			
	Without Metering	With Metering	Difference	Percent Difference	Without Metering	With Metering	Difference	Percent Difference
Southbound								
1. South of Harney/ County Line								
US 101	14,287	14,284	-3	0%	11,994	12,136	143	1%
I-280	18,691	18,809	118	1%	16,044	15,581	-463	-3%
% of total	62%	62%			67%	67%		
Arterials	20,462	20,258	-204	-1%	14,060	13,475	-585	-4%
% of total	38%	38%			33%	33%		
Total	*53,440*	*53,351*	*-89*	*0%*	*42,097*	*41,192*	*-905*	*-2%*
2. South of Millbrae Ave								
US 101	16,699	16,921	221	1%	15,398	15,558	161	1%
I-280	14,721	15,007	286	2%	13,865	13,314	-551	-4%
% of total	64%	65%			67%	67%		
Arterials	17,682	16,964	-718	-4%	14,487	14,052	-435	-3%
% of total	36%	35%			33%	33%		
Total	*49,102*	*48,892*	*-211*	*0%*	*43,750*	*42,925*	*-825*	*-2%*
3. South of Hwy 92								
US 101	15,520	14,630	-889	-6%	14,111	13,000	-1,111	-8%
I-280	17,538	17,570	33	0%	16,559	16,210	-350	-2%
% of total	71%	70%			66%	64%		
Arterials	13,624	13,841	217	2%	16,021	16,279	258	2%
% of total	29%	30%			34%	36%		
Total	*46,681*	*46,041*	*-640*	*-1%*	*46,691*	*45,489*	*-1,202*	*-3%*
4. South of Holly St								
US 101	17,583	17,533	-51	0%	16,356	16,655	299	2%
I-280	17,538	17,570	33	0%	16,559	16,210	-350	-2%
% of total	70%	70%			71%	71%		
Arterials	15,195	14,891	-304	-2%	13,745	13,216	-529	-4%
% of total	30%	30%			29%	29%		
Total	*50,316*	*49,994*	*-322*	*-1%*	*46,660*	*46,080*	*-579*	*-1%*
5. Marsh to Willow Rd								
US 101	11,259	11,374	115	1%	10,184	10,431	247	2%
I-280	15,529	15,240	-290	-2%	13,534	13,225	-309	-2%
% of total	64%	63%			62%	63%		
Arterials	14,989	15,631	642	4%	14,738	13,939	-799	-5%
% of total	36%	37%			38%	37%		
Total	*41,777*	*42,244*	*467*	*1%*	*38,456*	*37,594*	*-861*	*-2%*

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Table 2
2010 Screenline Peak Hour Volume Changes

	Forecasted Demand Volumes (Peak Hour[1])							
	AM				PM			
	Without Metering	With Metering	Difference	Percent Difference	Without Metering	With Metering	Difference	Percent Difference
Northbound								
1.South of Harney/ County Line								
US 101	12,581	12,597	16	0%	13,269	12,704	-566	-4%
I-280	14,727	14,529	-198	-1%	14,603	15,010	408	3%
% of total	64%	64%			62%	63%		
Arterials	15,171	15,238	67	0%	17,120	16,371	-749	-4%
% of total	36%	36%			38%	37%		
Total	*42,480*	*42,365*	*-115*	*0%*	*44,993*	*44,086*	*-907*	*-2%*
2. South of Millbrae Ave								
US 101	13,126	13,161	35	0%	14,851	14,652	-198	-1%
I-280	12,458	12,581	122	1%	13,750	14,127	378	3%
% of total	69%	70%			66%	66%		
Arterials	11,306	11,230	-77	-1%	14,685	14,645	-40	0%
% of total	31%	30%			34%	34%		
Total	*36,890*	*36,971*	*81*	*0%*	*43,285*	*43,424*	*139*	*0%*
3. South of Hwy 92								
US 101	14,030	13,253	-777	-6%	15,403	13,968	-1,435	-9%
I-280	15,714	15,845	130	1%	16,436	16,393	-43	0%
% of total	69%	69%			68%	68%		
Arterials	13,210	12,811	-399	-3%	14,714	14,567	-147	-1%
% of total	31%	31%			32%	32%		
Total	*42,955*	*41,909*	*-1,046*	*-2%*	*46,553*	*44,928*	*-1,625*	*-4%*
4. South of Holly St								
US 101	16,083	15,957	-126	-1%	16,087	15,600	-487	-3%
I-280	15,714	15,845	130	1%	16,436	16,393	-43	0%
% of total	72%	73%			71%	71%		
Arterials	12,598	12,041	-557	-4%	13,017	12,774	-242	-2%
% of total	28%	27%			29%	29%		
Total	*44,395*	*43,842*	*-553*	*-1%*	*45,540*	*44,768*	*-773*	*-2%*
5. Marsh to Willow Rd								
I-280	12,483	12,489	6	0%	13,992	14,118	126	1%
US 101	9,362	9,246	-116	-1%	10,050	9,851	-198	-2%
% of total	57%	58%			59%	60%		
Arterials	16,341	15,827	-513	-3%	16,884	16,263	-620	-4%
% of total	43%	42%			41%	40%		
Total	*38,186*	*37,563*	*-623*	*-2%*	*40,925*	*40,233*	*-692*	*-2%*

Note:
1. Peak hour demand was calculated by dividing the 3-hour peak period forecast by the appropriate peak factor (2.7920 for freeway links; 2.5994 for all other links).

Source: DKS Associates, 2004

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Table 3

2020 Screenline Peak Hour Volume Changes

	Forecasted Demand Volumes (Peak Hour[1])							
	AM				PM			
	Without Metering	With Metering	Difference	Percent Difference	Without Metering	With Metering	Difference	Percent Difference
Southbound								
1. South of Harney/ County Line								
US 101	13,966	14,234	268	2%	12,504	12,524	20	0%
I-280	19,159	18,703	-456	-2%	16,612	16,062	-550	-3%
% of total	62%	62%			65%	65%		
Arterials	20,627	20,594	-34	0%	15,946	15,247	-699	-4%
% of total	38%	38%			35%	35%		
Total	*53,752*	*53,530*	*-222*	*0%*	*45,062*	*43,833*	*-1,229*	*-3%*
2. South of Millbrae Ave								
US 101	16,885	16,914	29	0%	16,038	16,140	102	1%
I-280	15,078	15,092	14	0%	14,395	14,459	64	0%
% of total	65%	65%			65%	65%		
Arterials	17,012	17,585	573	3%	16,738	16,212	-527	-3%
% of total	35%	35%			35%	35%		
Total	*48,975*	*49,591*	*616*	*1%*	*47,172*	*46,811*	*-361*	*-1%*
3. South of Hwy 92								
US 101	15,704	16,489	785	5%	15,052	14,669	-383	-3%
I-280	18,117	17,936	-181	-1%	17,789	17,731	-58	0%
% of total	72%	71%			65%	64%		
Arterials	13,102	14,175	1,073	8%	17,943	18,435	492	3%
% of total	28%	29%			35%	36%		
Total	*46,923*	*48,600*	*1,678*	*3%*	*50,784*	*50,835*	*51*	*0%*
4. South of Holly St								
US 101	17,310	17,973	664	4%	17,516	17,290	-226	-1%
I-280	18,117	17,936	-181	-1%	17,789	17,731	-58	0%
% of total	70%	70%			69%	69%		
Arterials	15,505	15,158	-347	-2%	15,993	16,053	60	0%
% of total	30%	30%			31%	31%		
Total	*50,931*	*51,067*	*136*	*0%*	*51,299*	*51,074*	*-225*	*0%*
5. Marsh to Willow Rd								
US 101	11,711	11,123	-588	-5%	10,751	10,777	27	0%
I-280	16,072	15,481	-591	-4%	14,480	14,214	-266	-2%
% of total	63%	62%			61%	61%		
Arterials	16,061	16,215	153	1%	16,275	16,024	-250	-2%
% of total	37%	38%			39%	39%		
Total	*43,844*	*42,819*	*-1,026*	*-2%*	*41,506*	*41,016*	*-490*	*-1%*

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Table 3
2020 Screenline Peak Hour Volume Changes

	Forecasted Demand Volumes (Peak Hour[1])							
	AM				PM			
	Without Metering	With Metering	Difference	Percent Difference	Without Metering	With Metering	Difference	Percent Difference
Northbound								
1. South of Harney/ County Line								
US 101	13,285	13,090	-195	-1%	13,321	13,150	-171	-1%
I-280	15,204	14,886	-318	-2%	14,999	14,668	-331	-2%
% of total	63%	62%			62%	63%		
Arterials	16,387	16,963	576	4%	17,202	16,562	-640	-4%
	37%	38%			38%	37%		
Total	*44,876*	*44,939*	*63*	*0%*	*45,522*	*44,380*	*-1,142*	*-3%*
2. South of Millbrae Ave								
US 101	14,217	14,156	-61	0%	15,185	14,865	-320	-2%
I-280	13,302	13,451	149	1%	13,634	13,511	-122	-1%
% of total	68%	67%			65%	66%		
Arterials	12,922	13,340	418	3%	15,530	14,815	-714	-5%
% of total	32%	33%			35%	34%		
Total	*40,442*	*40,947*	*506*	*1%*	*44,349*	*43,192*	*-1,157*	*-3%*
3. South of Hwy 92								
US 101	15,326	14,770	-557	-4%	15,627	15,572	-55	0%
I-280	17,096	17,057	-39	0%	16,893	16,751	-141	-1%
% of total	69%	69%			67%	67%		
Arterials	14,242	14,498	255	2%	16,141	16,027	-114	-1%
% of total	31%	31%			33%	33%		
Total	*46,664*	*46,325*	*-340*	*-1%*	*48,661*	*48,350*	*-311*	*-1%*
4. South of Holly St								
US 101	17,635	17,683	47	0%	16,329	16,001	-328	-2%
I-280	17,096	17,057	-39	0%	16,893	16,751	-141	-1%
% of total	71%	71%			70%	70%		
Arterials	14,330	14,285	-45	0%	14,084	13,904	-180	-1%
% of total	29%	29%			30%	30%		
Total	*49,061*	*49,025*	*-36*	*0%*	*47,306*	*46,656*	*-650*	*-1%*
5. Marsh to Willow Rd								
I-280	13,719	13,643	-76	-1%	14,149	14,109	-40	0%
US 101	10,133	10,216	82	1%	10,091	10,051	-39	0%
% of total	58%	58%			57%	58%		
Arterials	17,366	17,528	162	1%	18,173	17,753	-419	-2%
% of total	42%	42%			43%	42%		
Total	*41,218*	*41,387*	*168*	*0%*	*42,412*	*41,913*	*-499*	*-1%*

Note:
1. Peak hour demand was calculated by dividing the 3-hour peak period forecast by the appropriate peak factor (2.7920 for freeway links; 2.5994 for all other links).

Source: DKS Associates, 2004

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Table 4
2010 Ramp Peak Hour Forecasted Volume Changes

	Average Peak Period Meter Delay		Forecasted Demand Volumes (Peak Hour[1])							
			AM				PM			
Ramp	AM	PM	Without Metering	With Metering	Difference	Percent Difference	Without Metering	With Metering	Difference	Percent Difference
101 Northbound										
University Loop	6	2	175	81	-94	-54%	354	75	-279	-79%
University Diag	1		565	461	-104	-18%	901	843	-58	-6%
Willow Loop	1	2	591	525	-66	-11%	972	624	-348	-36%
Willow Diag	1	3	502	368	-134	-27%	415	86	-329	-79%
Marsh Loop	1	2	230	218	-12	-5%	89	83	-6	-7%
Marsh Diag	1	3	3,650	3,648	-2	0%	4,116	3,669	-447	-11%
Woodside Loop	2		1,684	1,039	-646	-38%	1,180	1,812	632	54%
Woodside Diag		3	169	187	18	11%	179	75	-104	-58%
Whipple Loop	1	2	3,273	3,135	-137	-4%	3,730	2,961	-770	-21%
Whipple Diag			93	90	-3	-4%	50	53	3	6%
Holly Loop		1	2,190	1,815	-375	-17%	2,771	2,311	-460	-17%
Holly Diag	2	3	37	18	-18	-51%	108	75	-33	-31%
Marine (Ralston) Loop	1	2	53	120	67	127%	749	335	-414	-55%
Marine (Ralston) Diag	3	6	2,231	730	-1,501	-67%	2,241	1,125	-1,115	-50%
Hillsdale Loop	2	7	1,021	84	-937	-92%	1,096	132	-964	-88%
Hillsdale Diag	1	3	783	370	-413	-53%	666	93	-573	-86%
EB 92			393	380	-13	-3%	1,651	2,037	386	23%
WB 92			648	1,124	477	74%	925	1,157	232	25%
Kehoe			534	468	-66	-12%	420	662	243	58%
3rd Loop			988	795	-193	-20%	1,280	1,057	-223	-17%
3rd Diag			2,394	2,702	309	13%	2,978	2,656	-322	-11%
Pennisula			1,273	567	-706	-55%	688	878	190	28%
Anza Blvd			427	370	-57	-13%	1,009	952	-57	-6%
Broadway			1,933	2,489	556	29%	2,412	2,695	283	12%
Millbrae/Frontage Road			2,009	1,892	-118	-6%	2,537	2,384	-152	-6%
SFO Domestic			528	668	140	27%	978	1,036	58	6%
San Bruno			1,972	2,056	84	4%	2,427	2,197	-230	-9%
380/N Access			829	946	117	14%	1,648	1,732	84	5%
S Airport			514	469	-45	-9%	989	646	-343	-35%
Grand			1,093	1,076	-16	-1%	355	424	69	19%
Oyster Pt			2,550	2,273	-277	-11%	2,427	2,921	494	20%
Sierra Point			115	99	-16	-14%	160	166	6	4%
3COM Park			169	174	5	3%	69	69		
Total			*35,616*	*31,438*	*-4,177*	*-12%*	*42,569*	*38,021*	*-4,548*	*-11%*

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Table 4
2010 Ramp Peak Hour Forecasted Volume Changes

Ramp	Average Peak Period Meter Delay AM	Average Peak Period Meter Delay PM	Forecasted Demand Volumes (Peak Hour[1]) AM Without Metering	AM With Metering	AM Difference	AM Percent Difference	PM Without Metering	PM With Metering	PM Difference	PM Percent Difference
101 Southbound										
Harney Way			234	225	-8	-4%	189	140	-50	-26%
Sierra Pt		2	1,074	1,046	-28	-3%	600	411	-189	-31%
Bayshore	1	5								
Oyster Pt		4	375	417	42	11%	498	88	-410	-82%
S. Airport Bl			4,904	5,354	449	9%	4,762	4,521	-241	-5%
WB 380/SFO N Access			1,123	1,400	277	25%	514	745	232	45%
EB 380			4,620	4,192	-428	-9%	3,984	4,244	260	7%
San Bruno			1,943	1,771	-172	-9%	1,862	1,625	-237	-13%
SFO int'l travel			579	614	35	6%	15	300	286	1955%
SFO domestic travel			3,307	3,577	270	8%	3,208	3,130	-78	-2%
Millbrae Loop			500	1,819	1,319	264%	717	947	229	32%
Millbrae Diag	6		880	217	-663	-75%	557	304	-254	-45%
Broadway	2		3,707	3,621	-87	-2%	3,195	2,880	-315	-10%
Poplar			3,665	2,844	-821	-22%	2,096	2,452	356	17%
3rd Loop	4	3	1,167	122	-1,045	-90%	439	218	-222	-50%
3rd Diag	1	2	657	994	337	51%	1,296	845	-451	-35%
WB 92	5	5	2,699	1,859	-840	-31%	1,984	499	-1,485	-75%
Fashion Island	5	7	2,055	87	-1,969	-96%	2,284	364	-1,920	-84%
EB 92	7	6	1,075	536	-539	-50%	234	120	-115	-49%
Hillsdale Loop	2		3,699	3,785	87	2%	3,148	4,219	1,071	34%
Hillsdale Diag	6	8	1,520	396	-1,124	-74%	1,227	125	-1,102	-90%
Ralston/Harbor On			4,106	3,926	-180	-4%	3,458	3,481	23	1%
Holly CD (loop diag)	1	1	4,006	3,927	-79	-2%	3,260	2,987	-273	-8%
Brittan	3		3,796	1,912	-1,885	-50%	3,293	3,100	-194	-6%
Whipple Loop			13	29	16	124%	13	32	19	140%
Whipple Diag	4	3	1,012	766	-246	-24%	813	249	-564	-69%
Woodside	6	1	4,659	2,565	-2,094	-45%	3,637	3,298	-339	-9%
Marsh Loop	4	2	429	73	-356	-83%	5	5	1	17%
Marsh Diag	2	6	563	317	-245	-44%	78	77	-1	-1%
Willow Loop			3,134	3,275	142	5%	1,281	1,752	472	37%
Willow Diag	1	1	1,086	746	-340	-31%	481	316	-165	-34%
University			3,818	3,824	6	0%	2,173	2,169	-4	0%
Total			*66,406*	*56,237*	*-10,169*	*-15%*	*51,302*	*45,644*	*-5,658*	*-11%*

Table 4
2010 Ramp Peak Hour Forecasted Volume Changes

	Average Peak Period Meter Delay		Forecasted Demand Volumes (Peak Hour[1])							
			AM				PM			
Ramp	AM	PM	Without Metering	With Metering	Difference	Percent Difference	Without Metering	With Metering	Difference	Percent Difference
280 Northbound										
Sneath			1,688	1,318	-370	-22%	1,643	1,645	1	0%
Westborough Loop			211	536	325	154%	405	324	-80	-20%
Westborough Diag		3	155	192	37	24%	27	21	-5	-20%
Hickey			1,003	1,098	95	9%	1,014	1,322	308	30%
Serramonte			1,667	1,882	215	13%	1,898	1,757	-141	-7%
Northbound Hwy 1			3,068	3,034	-34	-1%	3,369	3,818	449	13%
Junipera Serra			2,504	2,191	-313	-13%	1,919	2,469	551	29%
Knowles			1,256	1,379	123	10%	1,297	1,672	375	29%
Total			*11,553*	*11,631*	*77*	*1%*	*11,572*	*13,029*	*1,457*	*13%*
280 Southbound										
John Daly			2,688	2,950	262	10%	1,530	1,602	72	5%
Southbound Hwy 1			820	931	111	14%	749	1,420	671	90%
Sullivan	8	7	1,783	1,687	-97	-5%	525	86	-439	-84%
Northbound Hwy 1			6,380	5,987	-393	-6%	4,702	4,438	-264	-6%
Hickey	1		1,510	1,448	-62	-4%	985	1,097	112	11%
Westborough			2,806	2,554	-252	-9%	1,060	1,246	185	17%
Avalon	1		4,625	4,741	116	3%	3,350	3,142	-209	-6%
Total			*20,613*	*20,298*	*-315*	*-2%*	*12,901*	*13,031*	*130*	*1%*

Note:
1. Peak hour demand was calculated by dividing the 3-hour peak period forecast by the appropriate peak factor (2.7920 for freeway links; 2.5994 for all other links).

Source: DKS Associates, 2004

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Table 5
2020 Ramp Peak Hour Forecasted Volume Changes

Ramp	Average Peak Period Meter Delay AM	Average Peak Period Meter Delay PM	AM Without Metering	AM With Metering	AM Difference	AM Percent Difference	PM Without Metering	PM With Metering	PM Difference	PM Percent Difference
101 Northbound										
University Loop	9	3	112	91	-20	-18%	471	105	-367	-78%
University Diag		1	904	973	69	8%	685	183	-502	-73%
Willow Loop	2	2	861	612	-249	-29%	964	419	-545	-57%
Willow Diag	2		416	187	-229	-55%	431	370	-62	-14%
Marsh Loop	2	2	474	308	-166	-35%	103	84	-19	-19%
Marsh Diag			3,845	3,989	144	4%	4,225	3,937	-288	-7%
Woodside Loop	4		2,381	924	-1,457	-61%	1,919	1,475	-444	-23%
Woodside Diag		1	173	243	70	40%	206	148	-58	-28%
Whipple Loop	2		4,117	3,888	-230	-6%	3,813	3,501	-312	-8%
Whipple Diag			106	93	-13	-12%	53	54	1	2%
Holly Loop			2,887	2,922	35	1%	2,923	2,926	3	0%
Holly Diag		2	125	125	0	0%	130	115	-14	-11%
Marine (Ralston) Loop	1		573	143	-430	-75%	343	638	295	86%
Marine (Ralston) Diag	3		2,341	2,407	66	3%	2,817	2,220	-597	-21%
Hillsdale Loop	5		983	108	-874	-89%	1,321	1,653	332	25%
Hillsdale Diag			700	816	116	17%	783	511	-272	-35%
EB 92			519	577	58	11%	1,311	1,659	348	27%
WB 92			836	427	-410	-49%	1,982	1,116	-866	-44%
Kehoe			654	683	29	4%	689	702	13	2%
3rd Loop			1,365	1,430	65	5%	1,563	1,517	-46	-3%
3rd Diag			2,747	2,741	-5	0%	2,875	3,055	180	6%
Pennisula			1,472	1,182	-290	-20%	1,036	1,092	57	5%
Anza Blvd			1,032	544	-488	-47%	962	942	-20	-2%
Broadway			2,586	2,301	-286	-11%	2,728	2,414	-314	-12%
Millbrae/Frontage Road			2,347	2,094	-254	-11%	2,518	2,476	-42	-2%
SFO Domestic			827	842	15	2%	1,048	1,093	45	4%
San Bruno			2,139	2,282	143	7%	2,264	2,301	37	2%
380/N Access			1,345	1,586	241	18%	1,965	1,958	-7	0%
S Airport			495	751	255	51%	838	588	-250	-30%
Grand			1,418	1,456	37	3%	1,365	617	-748	-55%
Oyster Pt			2,473	2,526	53	2%	2,842	2,502	-340	-12%
Sierra Point			155	193	38	25%	186	217	31	17%
3COM Park			177	185	7	4%	70	68	-2	-3%
Total			*43,589*	*39,627*	*-3,962*	*-9%*	*47,429*	*42,656*	*-4,773*	*-10%*

Table 5
2020 Ramp Peak Hour Forecasted Volume Changes

Ramp	Average Peak Period Meter Delay		AM				PM			
	AM	PM	Without Metering	With Metering	Difference	Percent Difference	Without Metering	With Metering	Difference	Percent Difference
101 Southbound										
Harney Way			255	241	-14	-6%	215	211	-5	-2%
Sierra Pt		1	883	619	-265	-30%	678	721	42	6%
Bayshore	4	1								
Oyster Pt		2	715	432	-282	-40%	475	51	-424	-89%
S. Airport Bl			4,922	4,890	-32	-1%	5,562	5,222	-340	-6%
WB 380/SFO N Access	1	10	1,092	568	-524	-48%	1,256	79	-1,177	-94%
EB 380			3,870	4,038	168	4%	4,274	4,182	-92	-2%
San Bruno		3	1,781	2,095	315	18%	2,042	112	-1,930	-95%
SFO int'l travel	1	1	727	266	-460	-63%	462	993	531	115%
SFO domestic travel		1	3,616	4,132	517	14%	3,398	3,183	-214	-6%
Millbrae Loop		1	560	953	394	70%	935	1,123	187	20%
Millbrae Diag	6	3	1,211	123	-1,088	-90%	528	107	-421	-80%
Broadway	2		4,177	3,620	-557	-13%	3,268	3,099	-169	-5%
Poplar			2,593	2,831	238	9%	2,613	2,414	-200	-8%
3rd Loop	4	2	644	376	-267	-42%	420	403	-17	-4%
3rd Diag	1		908	750	-158	-17%	1,334	1,265	-70	-5%
WB 92		3	2,447	2,676	229	9%	2,101	1,260	-841	-40%
Fashion Island		4	2,049	2,230	181	9%	2,515	160	-2,355	-94%
EB 92			772	1,630	858	111%	207	1,505	1,299	629%
Hillsdale Loop	1		3,674	3,921	248	7%	3,428	3,847	419	12%
Hillsdale Diag	6	5	1,894	144	-1,750	-92%	1,570	548	-1,022	-65%
Ralston/Harbor On		10	3,772	4,487	716	19%	4,176	3,043	-1,133	-27%
Holly CD (loop diag)		6	4,248	3,946	-302	-7%	4,341	2,067	-2,274	-52%
Brittan		10	3,333	3,912	578	17%	3,807	736	-3,071	-81%
Whipple Loop			17	15	-2	-14%	23	30	7	31%
Whipple Diag		2	989	929	-60	-6%	1,242	1,454	212	17%
Woodside		10	4,861	4,310	-551	-11%	4,231	1,974	-2,257	-53%
Marsh Loop	1		47	32	-16	-33%	5	12	7	158%
Marsh Diag		5	590	527	-62	-11%	136	76	-60	-44%
Willow Loop			3,163	3,284	121	4%	1,672	1,626	-47	-3%
Willow Diag	1	1	744	649	-95	-13%	719	464	-256	-36%
University			3,941	3,994	54	1%	2,985	2,659	-327	-11%
Total			*64,492*	*62,622*	*-1,870*	*-3%*	*60,619*	*44,623*	*-15,996*	*-26%*

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Table 5
2020 Ramp Peak Hour Forecasted Volume Changes

Ramp	Average Peak Period Meter Delay		AM				PM			
	AM	PM	Without Metering	With Metering	Difference	Percent Difference	Without Metering	With Metering	Difference	Percent Difference
280 Northbound										
Sneath		2	1,313	1,509	197	15%	1,974	686	-1,288	-65%
Westborough Loop		2	889	369	-521	-59%	743	88	-656	-88%
Westborough Diag		7	228	202	-26	-11%	19	35	16	84%
Hickey			1,230	1,135	-95	-8%	1,029	1,718	689	67%
Serramonte			1,847	1,818	-30	-2%	1,867	2,011	144	8%
Northbound Hwy 1			3,217	3,254	37	1%	3,395	2,844	-552	-16%
Junipera Serra			2,261	2,596	335	15%	2,181	2,551	370	17%
Knowles			1,396	1,489	93	7%	1,467	1,451	-15	-1%
Total			*12,381*	*12,372*	*-9*	*0%*	*12,676*	*11,385*	*-1,291*	*-10%*
280 Southbound										
John Daly		1	2,800	2,782	-18	-1%	2,097	1,187	-909	-43%
Southbound Hwy 1			781	2,414	1,633	209%	761	1,349	588	77%
Sullivan	10	10	1,628	95	-1,533	-94%	928	260	-668	-72%
Northbound Hwy 1			5,576	5,582	5	0%	5,162	4,918	-244	-5%
Hickey		1	1,795	1,383	-413	-23%	1,208	1,010	-198	-16%
Westborough			2,773	2,953	179	6%	1,541	1,627	85	6%
Avalon		1	4,928	4,792	-135	-3%	3,520	3,775	255	7%
Total			*20,282*	*20,000*	*-282*	*-1%*	*15,217*	*14,126*	*-1,091*	*-7%*

Note:
1. Peak hour demand was calculated by dividing the 3-hour peak period forecast by the appropriate peak factor (2.7920 for freeway links; 2.5994 for all other links).

Source: DKS Associates, 2004

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Table 6
2010 AM Peak Hour Level of Service Summary

Intersection		2010 AM with metering			2010 AM without metering		
		LOS	Avg Del (sec)	Crit V/C	LOS	Avg Del (sec)	Crit V/C
#30	Ralston Ave and Oracle Pkwy	F	>100	1.605	F	>100	1.328
#31	Ralston Ave and El Camino Real	E	57.2	1.016	F	>100	1.431
#33	Twin Dolphin / Redwood Shores	C	22.6	0.833	C	29.1	0.893
#107	Hillsdale Blvd and Edgewater Blvd	D	35.3	0.85	C	32.6	0.757
#121	Willow Rd and Middlefield Rd	F	>100	1.313	F	>100	1.376
#124	Harbor Blvd and Industrial Rd	B	15	0.732	C	22.3	0.664

Source: DKS Associates, 2004

Table 7
2010 PM Peak Hour Level of Service Summary

Intersection		2010 PM with metering			2010 PM without metering		
		LOS	Avg Del (sec)	Crit V/C	LOS	Avg Del (sec)	Crit V/C
#2	Oyster Pt / Dubuque ramps	F	>100	1.485	E	70.6	1.101
#4	Airport Blvd and Grand Ave	F	>100	1.423	F	85.1	1.356
#7	Grand Ave and Gateway Blvd	B	19.8	0.666	C	28.5	0.8
#23	4th Ave and Delaware St	D	35.7	0.911	C	26.2	0.812
#26	Hillsdale Blvd and Saratoga Dr	F	>100	1.273	F	>100	1.192
#29	Ralston Ave and WB 101 off-ramp	F	>100	1.775	F	>100	1.713
#30	Ralston Ave and Oracle Pkwy	F	>100	1.92	E	58	1.095
#33	Twin Dolphin / Redwood Shores	D	35.3	0.811	C	33.5	0.665
#37	WoodsideRd and Broadway St	F	>100	1.574	F	>100	1.227
#39	Marsh Rd and Bayfront Expy	F	>100	1.127	C	31.1	0.809
#122	Willow Rd and Bayfront Expy	C	34.3	0.828	C	22.3	0.628

Source: DKS Associates, 2004

Table
2020 AM Peak Hour Level of Service Summary

Intersection		2020 AM with metering			2020 AM without metering		
		LOS	Avg Del (sec)	Crit V/C	LOS	Avg Del (sec)	Crit V/C
#19	Poplar Ave and Humbolt St	F	>100	1.65	D	51.3	1.152
#25	Fashion Island Blvd and Norfolk St	F	>100	1.838	F	>100	1.79
#27	Hillsdale Blvd and Norfolk St	F	>100	1.219	E	63.2	1.033
#29	Ralston Ave and WB 101 off-ramp	F	>100	1.516	F	>100	1.414
#30	Ralston Ave and Oracle Pkwy	F	>100	1.918	F	>100	1.525
#31	Ralston Ave and El Camino Real	F	>100	2.164	F	>100	2.2
#107	Hillsdale Blvd and Edgewater Blvd	E	57.2	1.031	D	42.1	0.955

Source: DKS Associates, 2004

Table 9
2020 PM Peak Hour Level of Service Summary

Intersection		2020 PM with metering			2020 PM without metering		
		LOS	Avg Del (sec)	Crit V/C	LOS	Avg Del (sec)	Crit V/C
#9	San Bruno Ave and NB 101 ramps	C	34.9	0.887	D	40.3	0.94
#31	Ralston Ave and El Camino Real	F	>100	2.292	F	>100	1.809
#112	Holly St and El Camino Real	F	97.7	1.21	F	89.7	1.183
#114	Brittan Ave and El Camino Real	F	>100	1.565	F	>100	1.46

Source: DKS Associates, 2004

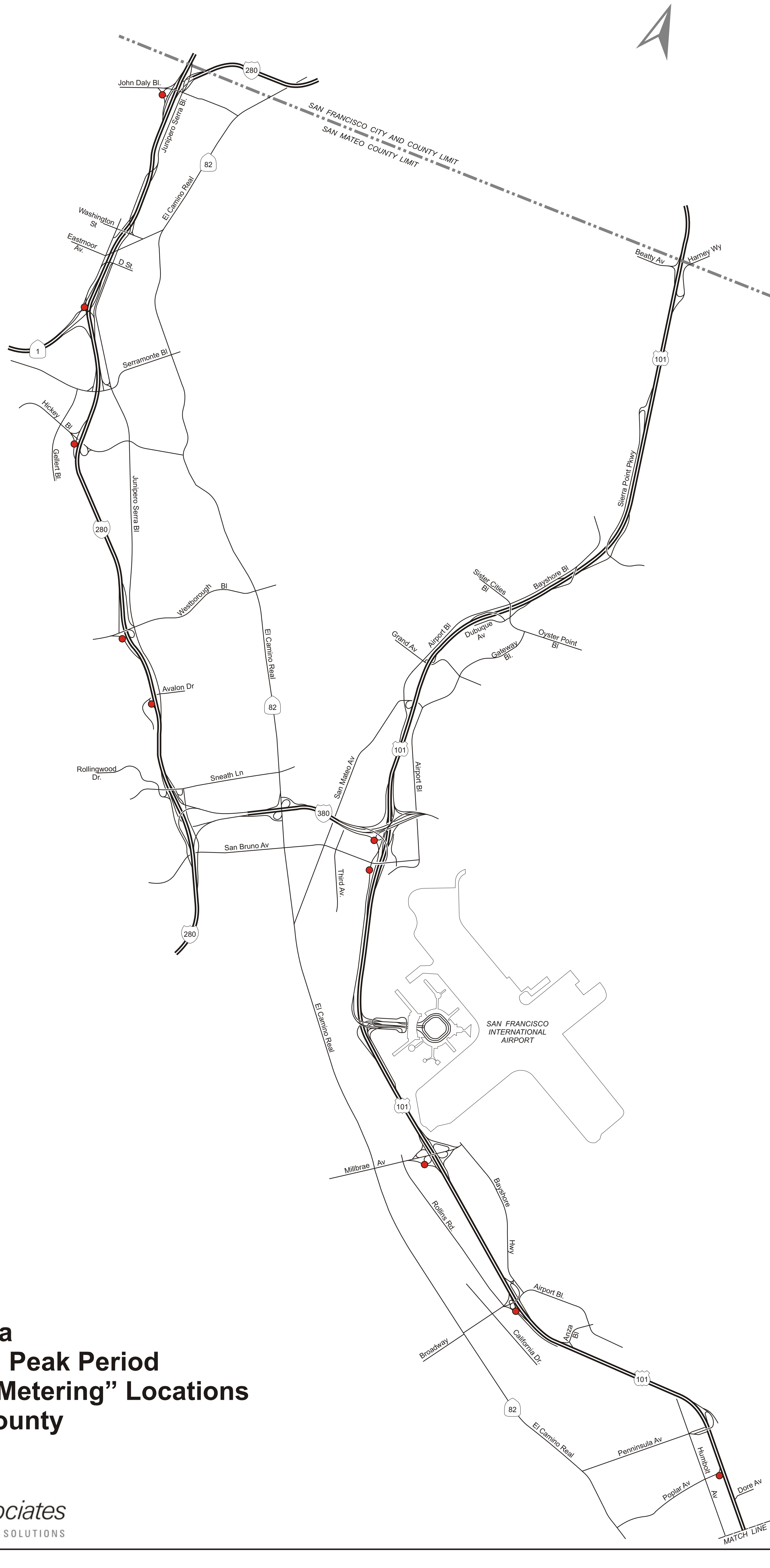

Figure 1a
2010 AM Peak Period
"Active Metering" Locations
North County

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P03018-2010 AM Rmp Mtrng1.cdr• 7/23/04

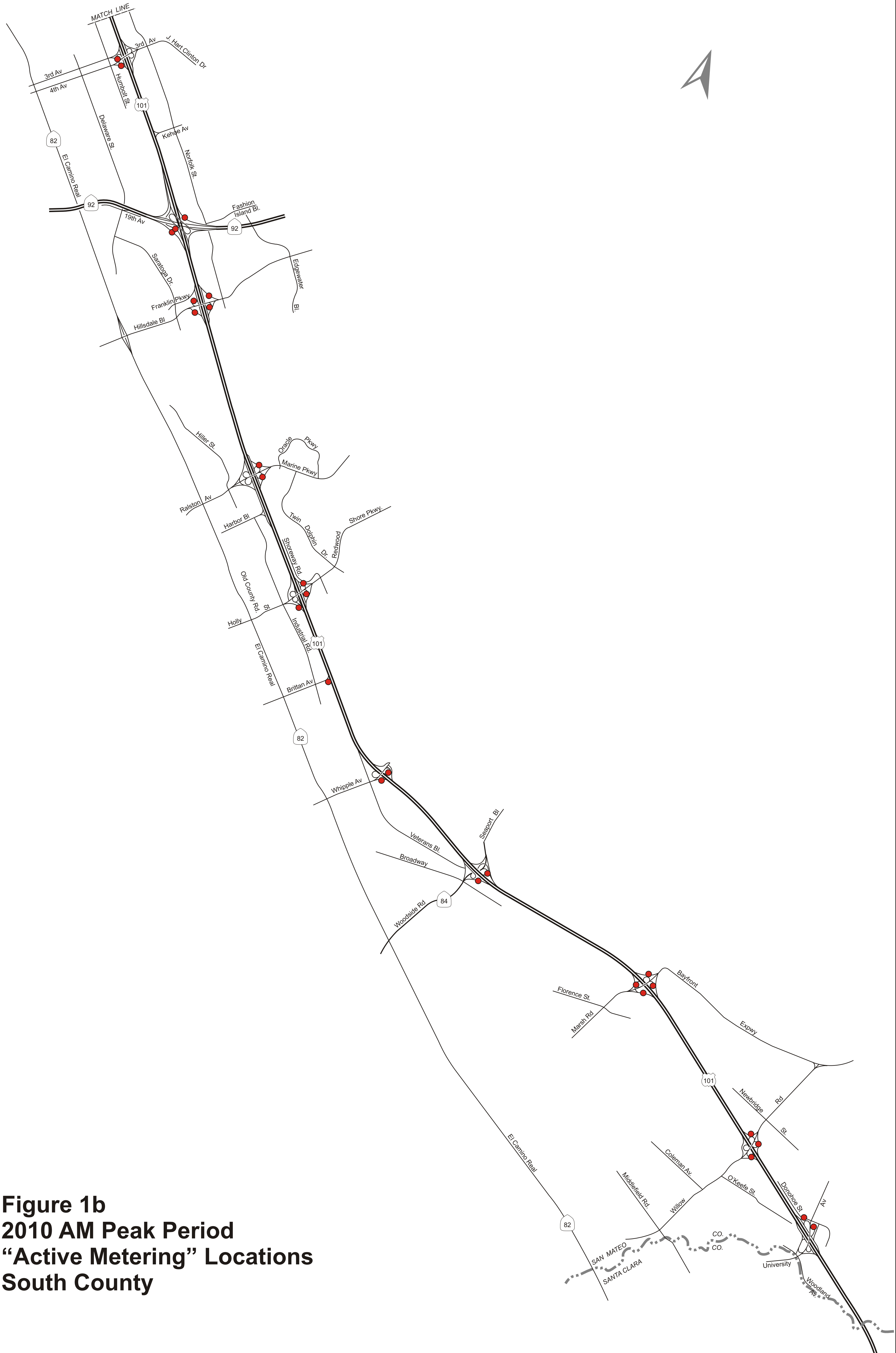

Figure 1b
2010 AM Peak Period
"Active Metering" Locations
South County

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P03018-2010AM Rmp Mtrng2.cdr•7/23/04

Figure 2a
2010 PM Peak Period
"Active Metering" Locations
North County

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P03018-2010 PM Rmp Mtrng1.cdr•7/23/04

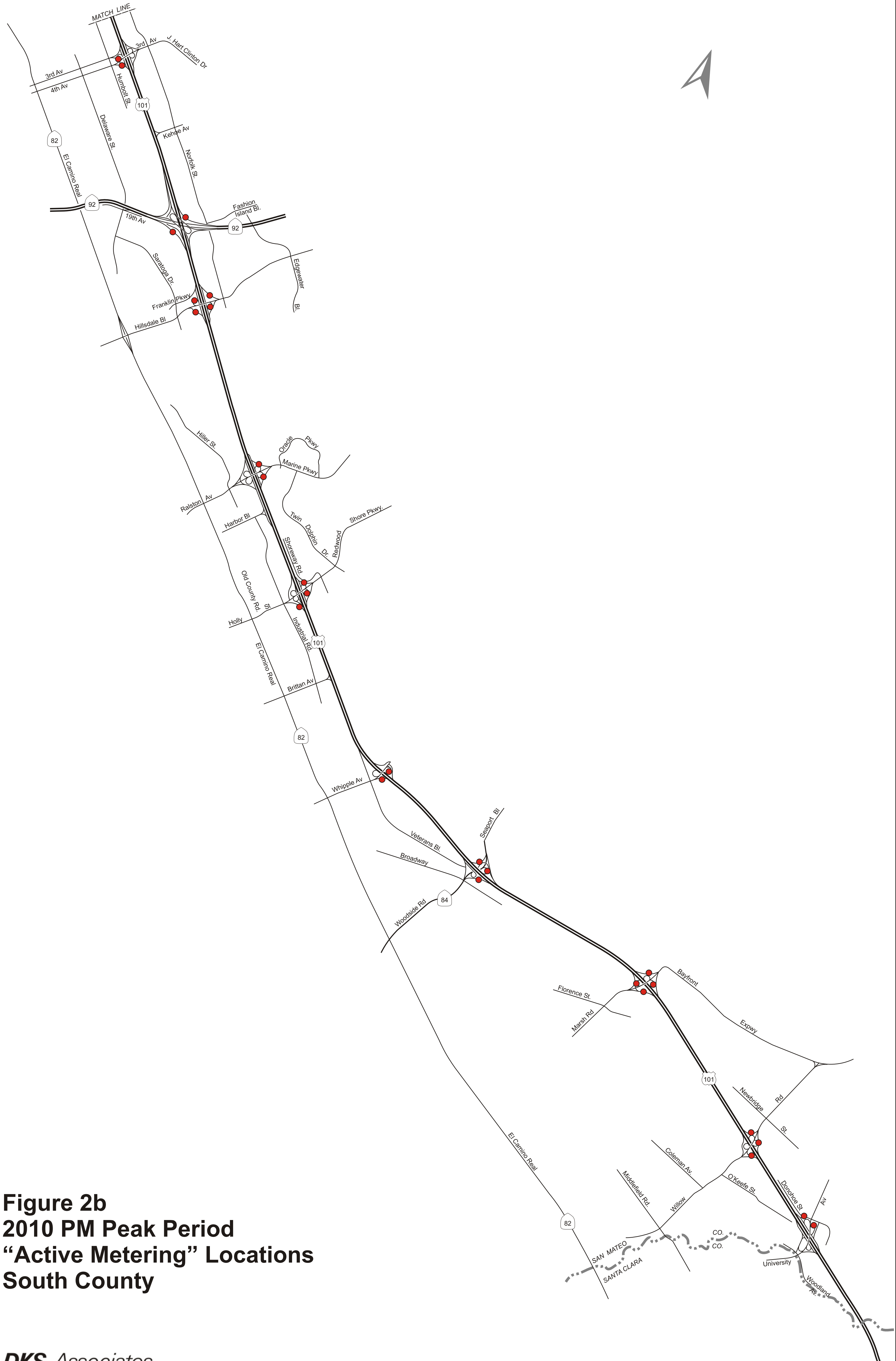

Figure 2b
2010 PM Peak Period
"Active Metering" Locations
South County

P03018-2010PM Rmp Mtrng2.cdr•7/23/04

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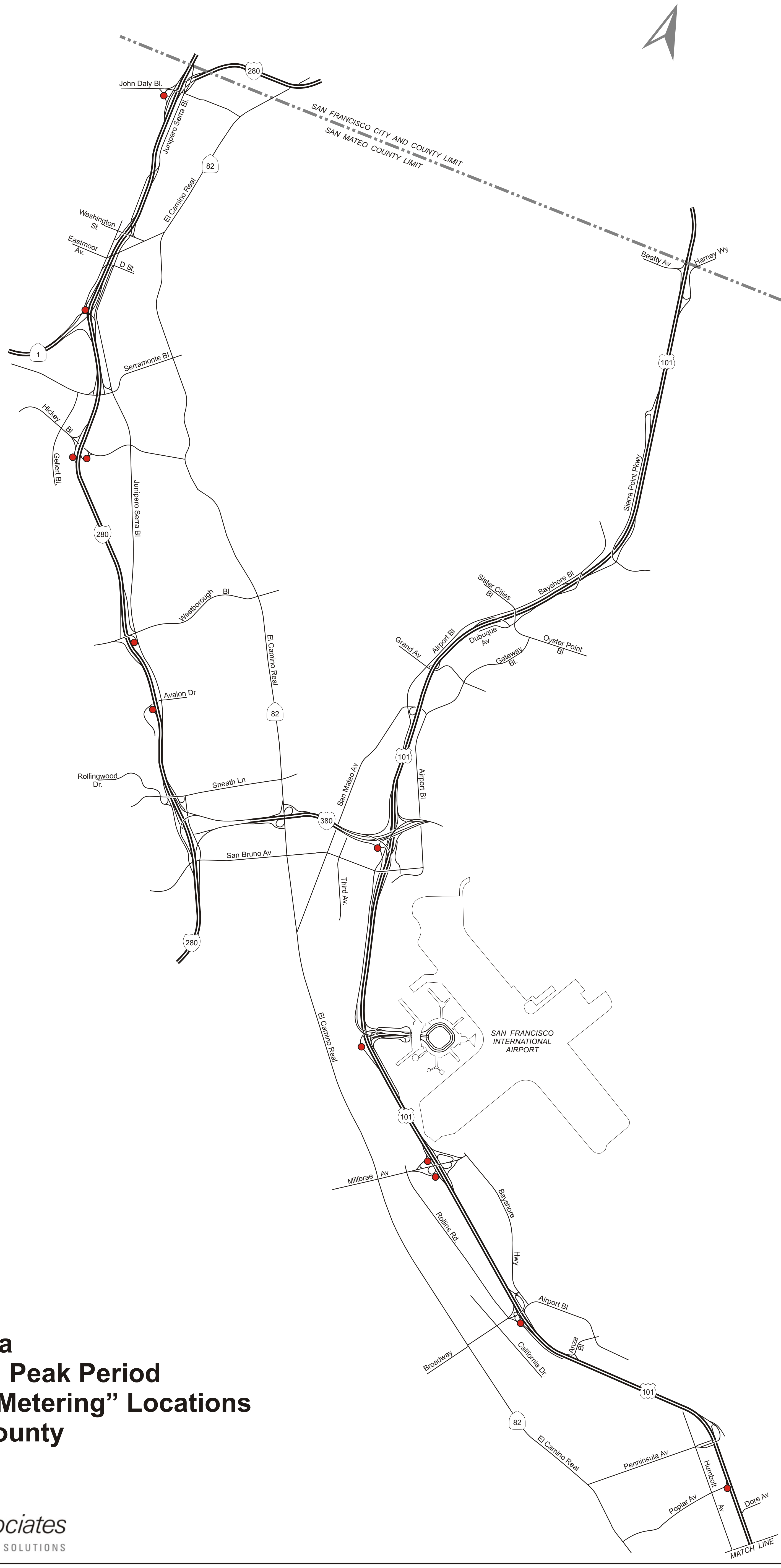

Figure 3a
2020 AM Peak Period
"Active Metering" Locations
North County

P03018-2020 AM Rmp Mtrng1.cdr•7/23/04

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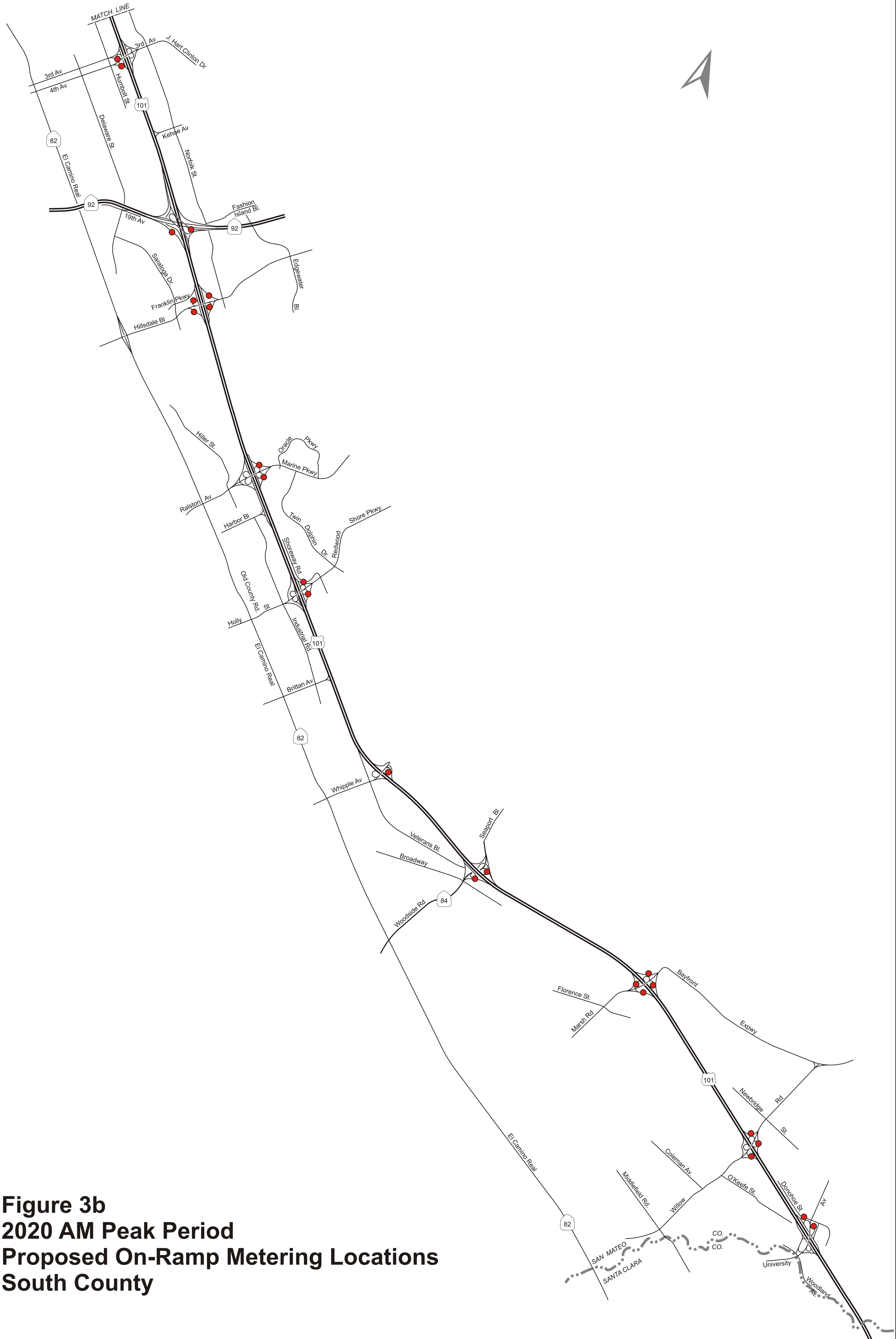

Figure 3b
2020 AM Peak Period
Proposed On-Ramp Metering Locations
South County

P03018-2020AM Rmp Mtrng2.cdr•7/23/04

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Figure 4a
2020 PM Peak Period "Active Metering" Locations North County

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P03018-2020 PM Rmp Mtrng1.cdr-7/23/04

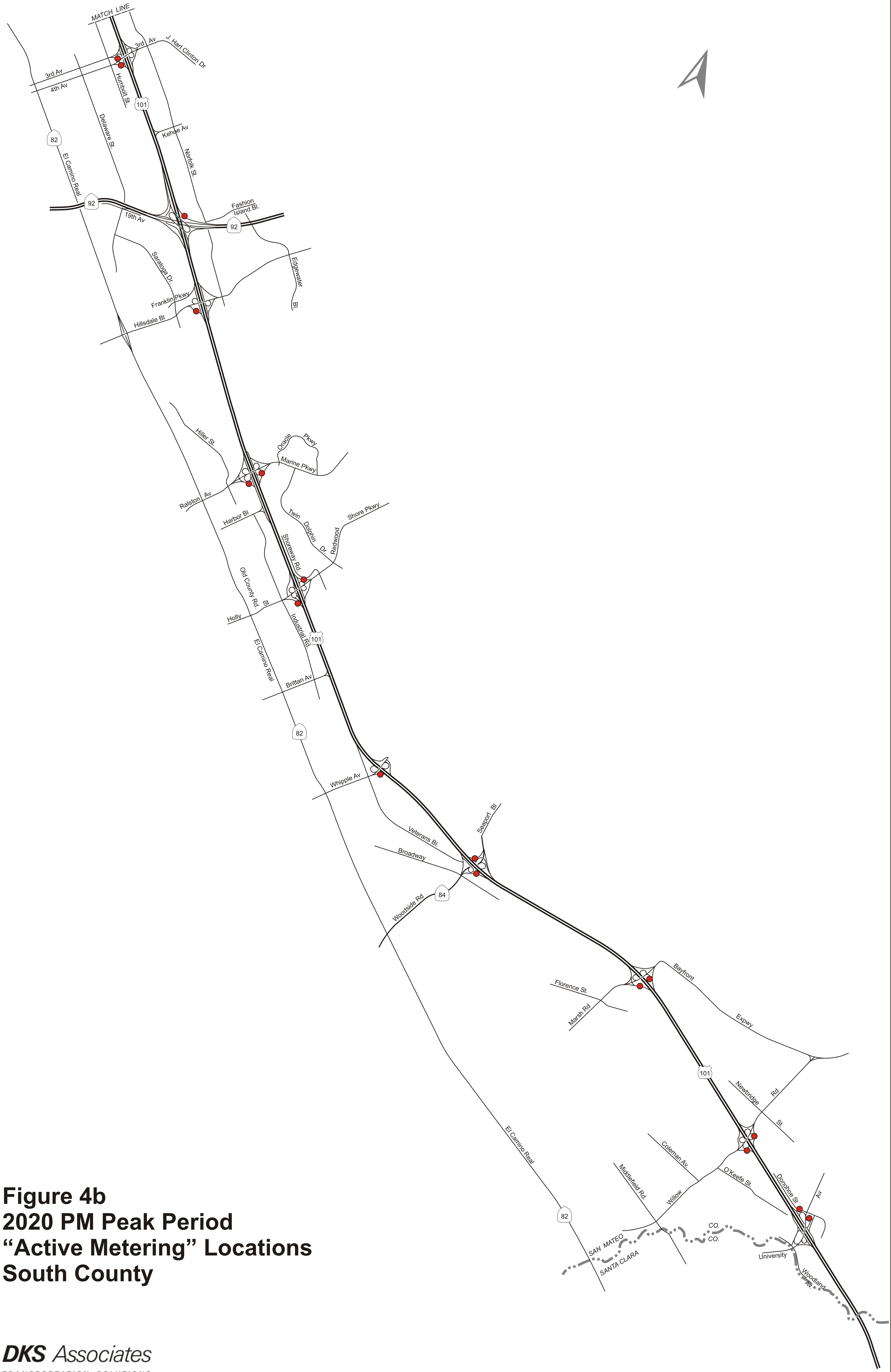

Figure 4b
2020 PM Peak Period
"Active Metering" Locations
South County

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P03018-2020PM Rmp Mtrng2.cdr•7/23/04

Figure 5
Screenlines

Figure 6a
Possible Study Intersections
North County

P03018-Possible Study Int 1.cdr-7/23/04

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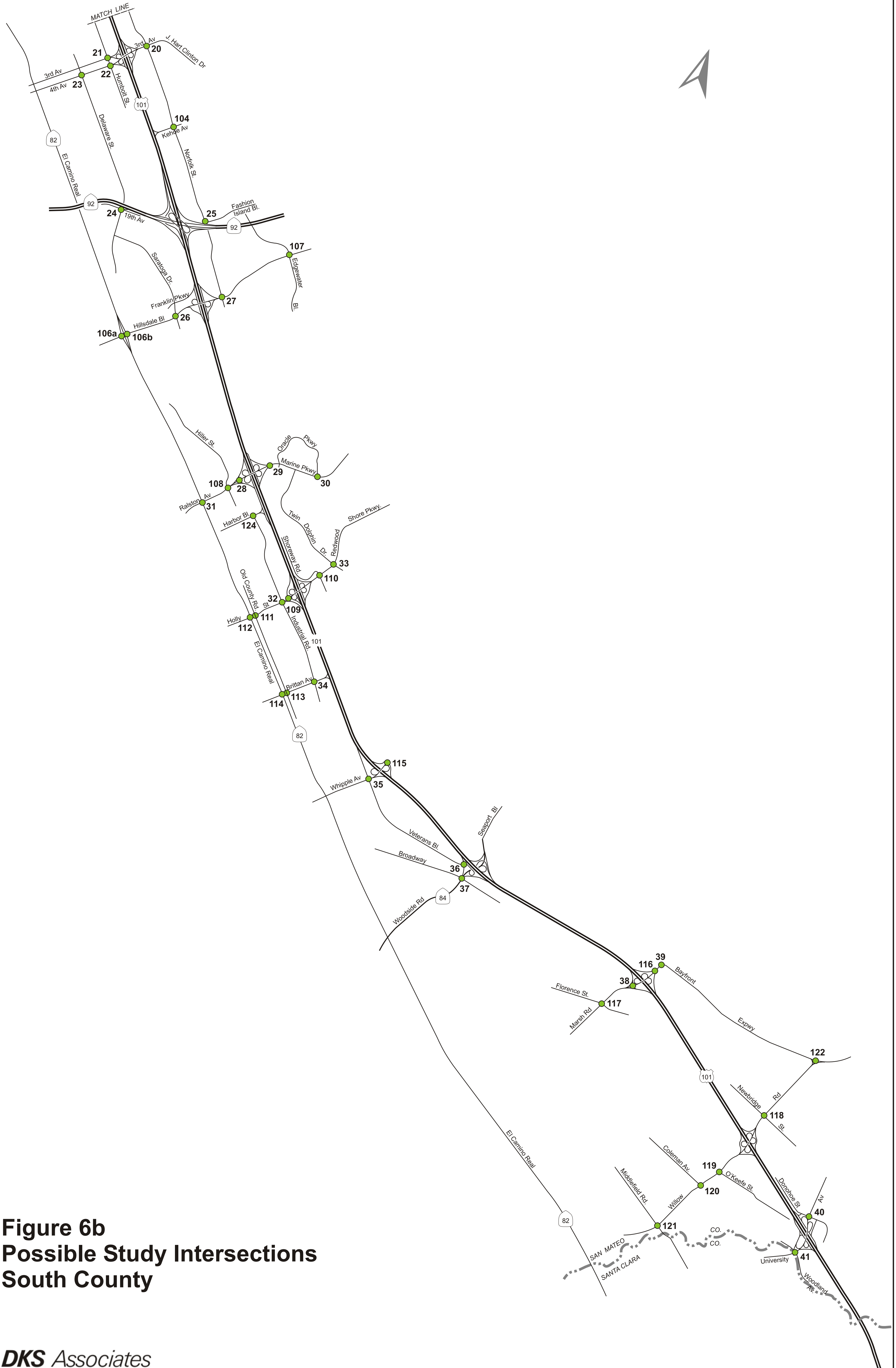

Figure 6b
Possible Study Intersections
South County

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P03018•Possible Study Int 2.cdr•7/23/04